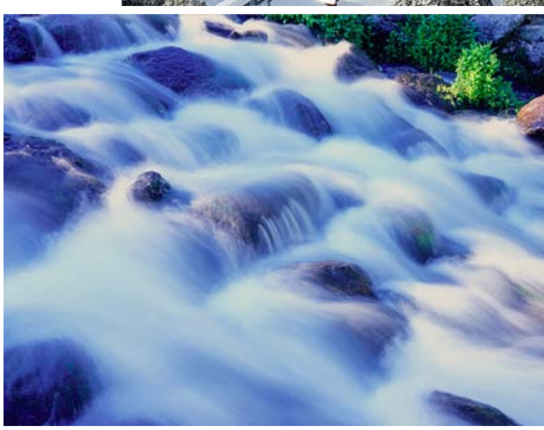
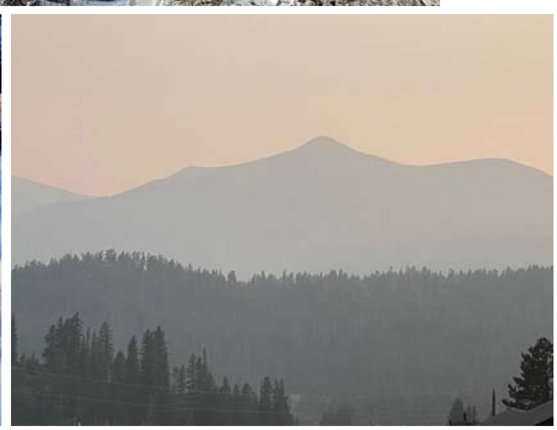
CLIMATE PROJECTIONS IN SUMMIT COUNTY, COLORADO





A report to Summit County, Town of Breckenridge, Town of Frisco, and NWCCOG Water Quality/Quantity Committee

the ROCKY MOUNTAIN CLIMATE Organization

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Updated December 2021

Climate Projections in Summit County, Colorado

By
Stephen Saunders, Tom Easley,
and Melissa Mezger

A report by the
Rocky Mountain Climate Organization

to
Summit County, Town of Breckenridge, Town of Frisco, and
Northwest Colorado Council of Governments Water Quality/
Quantity Committee
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the ROCKY MOUNTAIN CLIMATE Organization

The Rocky Mountain Climate Organization works to reduce climate disruption and its impacts to help keep the Interior West the special place we love. We do this in part by spreading the word about what a disrupted climate can do to us here, such as through reports like this, and also about what we can do to protect our climate.

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December 2021 update

This version of this report is an updated version of the report originally released in August 2021. The changes are the addition of a new figure (Figure 4), an update with final information on summer 2021 temperatures (on page 11), and miscellaneous minor corrections.

Dedication

This report and a companion report, *Climate Projections in Summit County, Colorado*, are both dedicated to Adam Palmer, who was the sustainability director for Eagle County until his untimely death in February of this year. Adam played an instrumental role in getting underway and shaping the project leading to these two reports—just one example of his many efforts to preserve and protect the quality of life in Colorado's mountains.

Acknowledgements

The authors wish to thank for providing assistance on this report: first and foremost, Torie Jarvis, Northwest Colorado Council of Governments Water Quality/Quantity Committee (QQ), via Dynamic Planning + Science, for her leadership in bringing together the local governments that with QQ sponsored this project and in managing this project; Alex Krebs, also of Dynamic Planning + Science; Jessie Burley and Haley Littleton, Town of Breckenridge; former County Commissioner Jill Hunsaker Ryan, John Gitchell, Maureen Mulcahy, and Justin Patrick, Eagle County; Mayor Hunter Mortenson, Don Reimer, Gilly Plog, and Ryan Thompson, Town of Frisco; former County Commissioner Karn Stiegelmeier, Nicole Valentine, and Michael Wurzel, Summit County; Kristen Bertuglia and Suzanne Silverthorn, Town of Vail; Mike Nathan, Arapahoe Basin Ski Area; and John Fielder.

Cover photos, clockwise from the top: Breckenridge and wildfire smoke over Peak 8, provided by Summit County, and Gore Range creek, provided by and © John Fielder.

Contents

Executive Summary

This analysis of climate change projections for Summit County, Colorado, shows how much this area has at stake as human activities continue to change the climate, and how much difference it can make locally—how much the local climate would be protected—if heat-trapping emissions are sharply reduced.

This report, and a parallel one covering Eagle County, Colorado, identify in detail what climate models project for future local temperature and precipitation. Each report analyzes 24 million individual projections of daily high and low temperatures and precipitation amounts:

- downscaled to produce local results for three specific areas in the county;
- using four different scenarios of future levels of heat-trapping pollution;
- derived from 12 to 20 global climate models per emission scenario; and
- covering four 20-year periods across the rest of this century.

Hotter summers

The most striking projections are for how much hotter Summit County summers could become unless heat-trapping emissions are sharply reduced.

The following examples are with high future heat-trapping emissions for the Frisco/Dillon Reservoir area, including Frisco and the other communities around Dillon Reservoir and also representative of Breckenridge. The hottest days of the year in this area are projected, according to the median projections from multiple models:

- In typical mid-century (2040–2059) years, to average 85°—compared to 79° in 1970–1999.
- In the extreme year in mid-century, to be 88°—compared to 82°, the hottest single day in 1970–1999.
- In typical late-century years (2080-2099), to average 90°.
- In the extreme year in late century, to get as hot as 94°.

So an *average* summer day in mid-century could be three degrees hotter than the single hottest day of the late 20th century.

Even more telling might be how much more common hot days could become. Days 80° and hotter per year, according to the median projections:

- In typical mid-century years, would average 12 days—a thirty-fold increase over the baseline years, which averaged 0.4 such day every year.
- In the extreme year in mid-century, would occur 37 times—more than a full month's worth. That compares to a high of four such days in 1970–1999.
- In typical years late in the century, would average 54 days—nearly two months's worth.
- In the extreme year late in the century, would occur 89 times—essentially all summer long.

The above projections are for average conditions across a grid of 18 miles by 14 miles, within which temperatures would vary with elevation. Frisco and Breckenridge are at lower elevations than the average for this grid, so their actual temperatures would be higher than the grid's averages. High temperatures in Frisco might be 3° hotter than the average for the grid, and Breckenridge might be about 1° hotter.

Sharp emission reductions halt temperature changes

There is good news, too, from this analysis—it also shows how completely the above changes can be avoided if global emissions of heat-trapping pollution are sharply reduced. With low future emissions (as well as with the other emission scenarios), temperatures in 2020–2039 would be higher than they were in 1970–1999. But with low future emissions, they would not continue climbing after that.

The following median projections for the same Frisco/Dillon Reservoir area, but now with low future emissions, illustrate that.

The hottest days of the year:

- In 2020–2039 in typical years, would average 82°, three degrees higher than in 1970–1999.
- Then would remain essentially the same for the rest of the century—averaging 83° in 2040–2059, then 82° in both 2060–2079 and 2080–2099.

Also in this area and also with low emissions, days 80° and hotter are projected:

- In 2020–2039 in typical years, to average three such days per year (compared to 0.4 day per year in 1970–1999).
- Then to stay the same thereafter, also averaging three such days in each of the next 20-year periods.

Warmer winters and earlier spring warm-up

Winters are also projected to get warmer. Temperatures were analyzed for the stretch from November 15 of one year to April 15 of the next year, chosen to approximate the core season for both snowpack accumulation and skiing and other snow-dependent sports. In the Breckenridge/Quandary area (including the Breckenridge Ski Resort) with high emissions, the median projections are that days with high temperatures above 32°:

- In mid-century typical years, would average 23 percent of the days in that snow/ski season—compared to 12 percent in 1970–1999.
- In the hottest mid-century year, would be 41 percent of those days—compared to a high of 25 percent in 1970–1999.
- In late-century typical years, would average 38 percent of those days, and in the extreme year would be 58 percent.

Days in late winter and early spring are also projected to warm up earlier. This analysis identifies projected changes in days that are 40° or hotter, warm enough to cause snowmelt and slushy skiing. For the stretch of March 16 through April 15, the last month of the core snow/skiing season, days that warm are projected for the Breckenridge/Quandary grid with high emissions:

- In mid-century typical years, to average 48 percent of the days in that stretch of 31 days—compared to a historical average of 30 percent.
- In the hottest year in mid-century, to be 73 percent of those days—compared to a high of 55 percent in 1970–1999.
- Late in the century, in typical years to average 63 percent and in the extreme year to be 79 percent of those late-season days.

Precipitation

Projections about precipitation are less certain than those about temperatures. Also, projections about summer precipitation are especially uncertain here because the models do not well represent this region's summer monsoons. But the models are consistent in suggesting two changes in precipitation changes that are particularly noteworthy.

First, the models generally project that for the cold months of the year (November through April) continued heat-trapping emissions will lead to increased precipitation. For example, in the Vail Pass/North Tenmile Creek area with high emissions, the median projections are that the amount of cold season precipitation is projected:

- In mid-century typical years, to increase by seven percent, compared to 1970–1999.
- In late-century typical years, to increase by seventeen percent.

Second, the models project that days with a modest amount of precipitation (less than one-quarter inch) will become less frequent but that days with heavier precipitation amounts will become more frequent. Again using as the example the Vail Pass/North Tenmile Creek area, the median projections are that with high emissions:

- Wet days with less than a quarter-inch of precipitation are projected to average four percent less frequent in mid-century, and nine percent less frequent late in the century, compared to 1970–1999.
- Days with a quarter-inch to a half-inch of precipitation are projected to average fifteen percent more frequent in mid-century, and 23 percent more frequent late in the century.
- Days with a half-inch or more of precipitation are projected to average eighteen percent more frequent in mid-century, and 33 percent more frequent late in the century.

Consequences

Assessing the impacts of these and other climate changes is beyond the scope of this report, but it is well documented in the scientific literature that the climate changes of the type projected here are likely to lead to a wide range of impacts, including the following.

- Higher temperatures increase the acreage burned in wildfires and the length of the wildfire season. Projections range up to a nearly seven-fold increase in this region in area burned with only a modest increase in temperatures.
- Increases in wildfires obviously threaten people's safety and property, particularly as development expands in fire-prone areas. More wildfire smoke also increases the risk of respiratory disease and mortality, and heavy precipitation on burned areas leads to more debris flows, such as the mudslides this summer in Colorado that have repeatedly closed mountain highways.
- The season for skiing, snowboarding, and other snow-dependent sports could be shorter and the snow slushier—reducing enjoyment for skiers, profits for skiing-dependent businesses, and tax revenues for state and local governments. If ski areas do not experience long enough stretches of sub-freezing temperatures, it is conceivable they will not be able to maintain snowy slopes, regardless of whether they have snowmaking equipment or the water supply, shortening the length of the ski season.
- Increased temperatures, especially the earlier occurrence of spring warmth, have already altered the water cycle across the West, with changes that include decreases in snowpack and its water content, earlier streamflows, and shifts in precipitation from snow to rain.
- Higher temperatures decrease water availability, by increasing evaporative losses from water bodies, soils, and plants, and increase irrigation requirements for crops and other outdoor plants.
- Higher temperatures and reduced river flows can reduce opportunities for fishing and rafting. Other impacts to summertime recreation and tourism could include losses of visitation and visitor enjoyment, for reasons ranging from temperatures too high for outdoor activities to disrupted transportation systems.
- Higher temperatures, especially if combined with drier summers, can increase tree mortality. In Colorado, tree mortality in subalpine forests has increased in recent decades, with the greatest increases occurring during hot, dry periods.
- Hotter and drier conditions can drive outbreaks of insects such as bark beetles as trees lose their resistance to infestations and as winters no longer have enough deep cold to limit beetle populations, allowing them to reach epidemic levels.

Especially when considered with additional scientific information on these and other possible impacts, the local climate projections analyzed in this report can help local governments, stakeholders, and the general public assess the possible future extent of these projected changes and their impacts in Summit County, and guide public and private decisions about taking actions both for climate protection and for climate change preparedness.

1. Introduction

This analysis of climate change projections for Summit County, Colorado, shows how much this area has at stake as human activities continue to change the climate, and how much difference it can make locally—how much the local climate would be protected—if heat-trapping emissions are sharply reduced.

Analysis overview

This report, and a parallel one covering Eagle County, Colorado,[1] identify in detail what climate models project for future local temperature and precipitation. Each report analyzes 24 million individual projections of daily high and low temperatures and precipitation amounts:

- downscaled to produce local results for three specific areas in the county;
- using four different scenarios of future levels of heat-trapping pollution;
- derived from 12 to 20 global climate models per emission scenario; and
- covering four 20-year periods across the rest of this century.

The analysis draws on the methodology developed in two parallel 2015 Rocky Mountain Climate Organization reports focused on Boulder and Larimer counties, funded by the Colorado Department of Local Affairs using federal disaster recovery funds, to help those localities and others prepare for wildfire and flooding threats as they become more extreme from continuing climate change, and expanded upon for two 2017 reports on projections for extreme heat and for precipitation in the Denver metropolitan area, funded by the City and County of Denver's Department of Environmental Health.[2] For the current reports, this methodology was adapted to focus on the climatic conditions most important in Colorado's mountains. The Denver reports and the two new reports are, as far as the authors are aware, the most detailed analyses yet done of climate model projections for any locality. This is in part because these three reports analyze not just future average conditions but also future temperatures in extreme years—in the projected hottest year in each succeeding 20-year period over the rest of this century.

The analyses for Summit and Eagle counties certainly are the most detailed analysis of the details of climate model projections for Colorado mountain locations, and should be of interest not only in those counties but also in other locations in the Southern Rocky Mountains that could experience similar changes.

The projections analyzed in this report are from global climate models that have been downscaled to produce local results and made available on an online archive created by federal agencies and others.[3] Similar downscaled projections have been used in many previous analyses, notably in this state *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation (Second Edition—August 2014)*, a report prepared by the Western Water Assessment (WWA) program at the University of Colorado Boulder for the state government's Colorado Water Conservation Board.[4] This WWA report remains the primary overall source focused on what climate change may be like in Colorado. In its report, WWA reported on many ways that climate change could be manifested in the state, including that with continued high increases in future heat-trapping emissions, statewide average temperature could increase by 2035–2064 by 2.5° to 5.5°* compared to 1971–2000 under the emission scenario identified in this report as "medium #1", or by 3.5° to 6.5° under the "high emissions" scenario (see page 7 for details on those scenarios). (These temperature ranges cover the middle 80 percent of the available projections from climate models, as illustrated by Figure 3 on page 9, but without a median projection).

The analysis done for this report differs from and adds to the WWA report in several ways:

- First and most importantly, this report analyzes model projections for conditions that could occur on individual days—projected high and low temperatures and precipitation amounts for every individual day from January 1, 2020, through December 31, 2099 (plus retrospective projections for daily

*All temperatures presented here are in degrees Fahrenheit.

conditions in the 1970–1999 baseline). Projections for individual days have no particular reliability, but an analysis of the average and extreme daily conditions projected to occur over the 20-year periods used here identifies in detail how the models suggest that the future climate may change. Analyzing daily data in this way is rare, as it requires analyzing literally millions of more individual projections than the few thousands of projections for future decadal, annual, seasonal, and monthly averages typically analyzed by scientists (including by WWA in its report). The far more laborious process of analyzing daily projections makes it possible to identify such details as how often the models project that daily temperatures could reach certain thresholds.

- Second, this report considers projections from all four current scenarios for future levels of heat-trapping emissions (described on the next page). Considering all scenarios shows the full range of possibilities embodied in the models and shows how much difference will be made by the extent to which global emissions are reduced.
- Third, this analysis covers the full century, with results presented for four 20-year time periods—2020–2039, 2040–2059, 2060–2079, and 2080–2099. The first of those periods is a time span we have just entered, and covers the immediate planning horizon for local governments and others. Together, all four periods cover the expected lifetimes of children alive today.

For more, see the Methodology section on pages 47–48.

Geographic area

This analysis covers three separate, contiguous grids in Summit County, each one-quarter of a degree of latitude by one-quarter of a degree of longitude, or about 18 miles by 14 miles. Grids of this size are the smallest units for which the projections from the global climate models have been downscaled to yield local projections. These three grids, shown in Figure 1 on the next page, are identified in this report as:

- The Frisco/Dillon Reservoir grid, with elevations from about 9,000 to about 12,900 feet above sea level, with the lowest average elevation of these three grids. The grid includes Frisco, the northern portion of Breckenridge, portions of Silverthorne and Dillon, and unincorporated areas around Dillon Reservoir. The average high temperature in this grid in 1970–1999 was 48°, the average low temperature was 19°, and precipitation averaged 20 inches per year (see the tables at the end of the temperature and precipitation sections). Because the above named towns, including all of Breckenridge, are lower than the grid's average elevation, they would have higher temperatures than the grid's average (see the "caveat" below). This grid, however, would come the closest of the three grids in representing the temperatures of all these towns.
- The Breckenridge/Quandary grid, ranging from about 9,600 to 14,300 feet. The grid includes most of the town of Breckenridge—but, as stated above, because of its elevation the town itself is better represented by the Frisco/Dillon Reservoir grid (also see below). The grid includes the Breckenridge Ski Resort and other slopes and peaks of the Tenmile Range, to Quandary Peak at the range's southern end. The average high temperature in this grid in 1970–1999 was 43° (five degrees cooler than the Frisco/Dillon Reservoir average), the average low temperature was 16°, and the average annual precipitation was 31 inches.
- The Vail Pass/North Tenmile Creek grid, from about 9,200 to about 12,500 feet in elevation. The grid includes the drainage for North Tenmile Creek, the water supply for the Town of Frisco. The average high temperature in this grid in 1970–1999 was 44°, the average low temperature was 15°, and the average annual precipitation was 31 inches—all similar to the averages for the Breckenridge/ Quandary grid.

Caveat: Temperatures vary within grid

In the database of climate projections analyzed for this report, the values for temperature and precipitation are average values across a particular grid. All of these three grids include many different elevations, and temperature varies with elevation—decreasing by an average of about 3.4° with every 1,000 feet of additional elevation.[5] This means that a grid's average temperature best represents the conditions at a grid's average elevation, and that a particular location at an elevation lower than that would be warmer than the grid's average and one at a higher elevation would be cooler.

A weather station near the shore of Dillon Reservoir, just inside the Frisco/Dillon Reservoir grid, provides an example that can be documented. The station is at 9,081 feet, one of the lowest elevations within that grid. Its average summertime (June-July-August) high temperature in the 1970–1999 baseline period was 71°.[6] That is 3° hotter than the grid's comparable baseline value, reflecting the weather station's lower elevation. The towns of Frisco, Silverthorne, and Dillon are all at essentially the same elevation as the weather station, and could all be expected to also have summertime highs about 3° above the grid's average. The town of Breckenridge, at 9,600 feet, would also be warmer than the grid's average, probably

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Summit County grids analyzed in this report

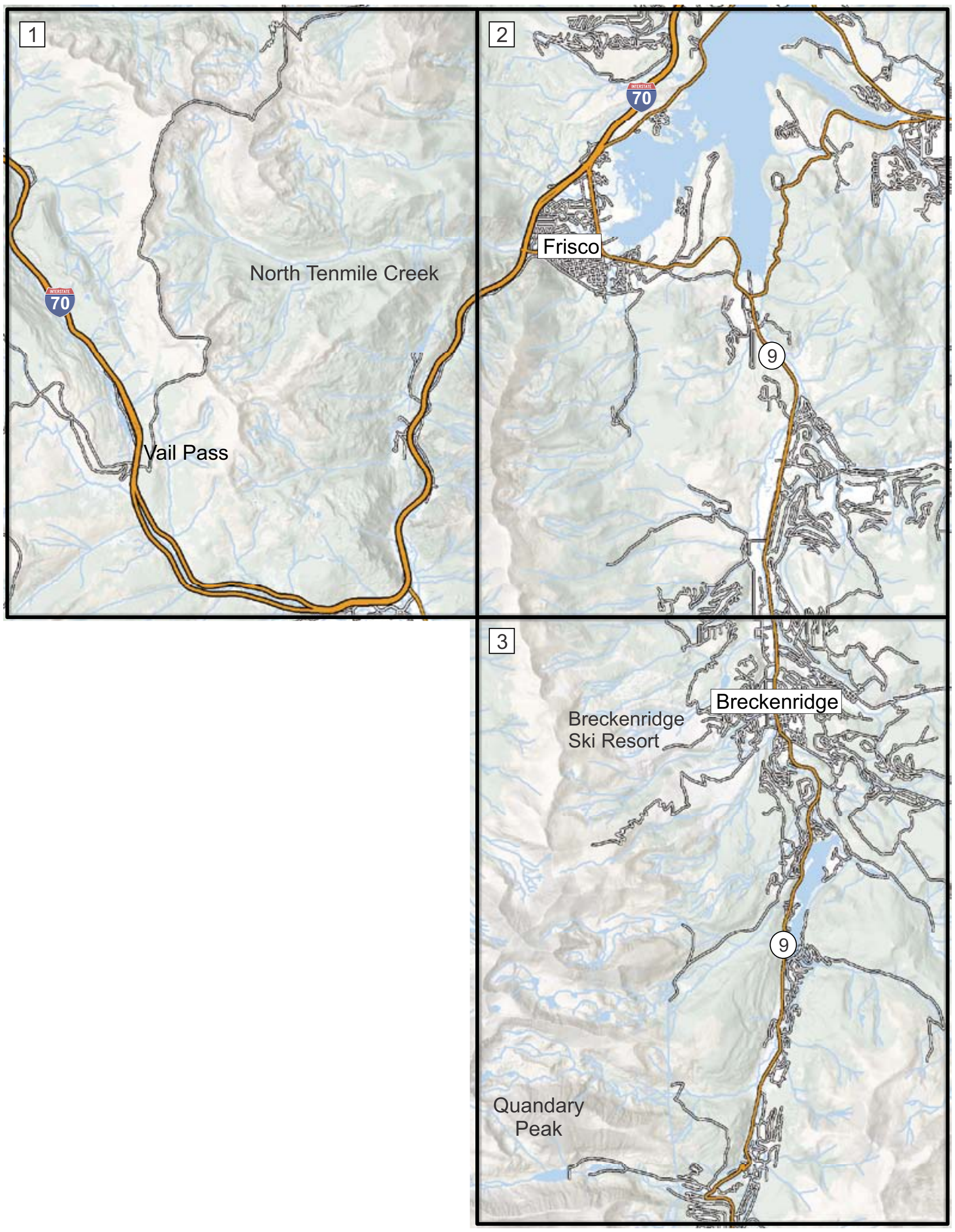


Figure 1. The three grids for which climate projections were separately analyzed for this report: (1) the Vail Pass/North Tenmile Creek grid, (2) the Frisco/Dillon Reservoir grid, and (3) the Breckenridge/Quandary grid.

by about 1°. So the projections for the Frisco/Dillon Reservoir grid, while the best available for representing all four of these towns, likely understate the temperatures that would occur in the towns.

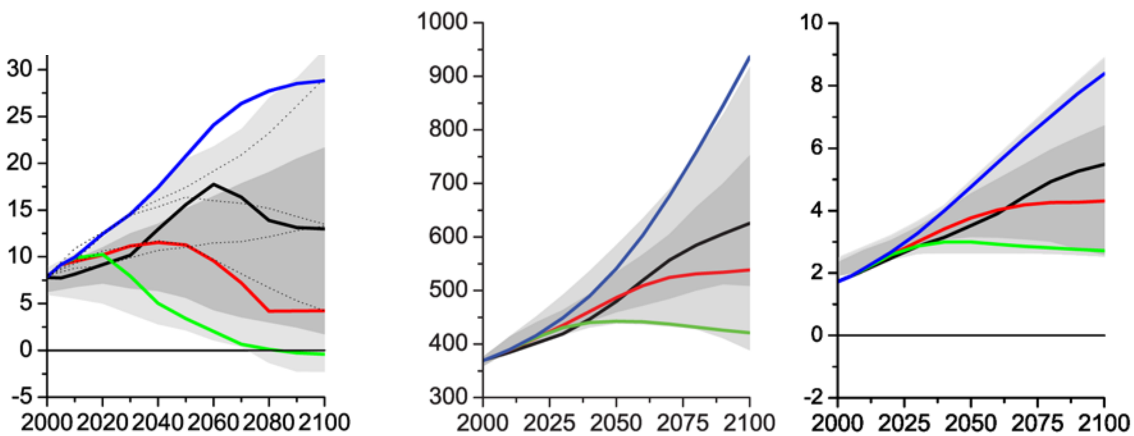
Emissions scenarios

Projections of the future climate vary depending on what is assumed about future levels of heat-trapping emissions, because the magnitude of future climate change depends primarily on cumulative emissions of heat-trapping gases and how sensitive Earth's climate is in responding to those emissions.[7]

The four emission scenarios illustrating possible futures used to drive the climate projections analyzed in this report[8] are:

- What is called here the **high** scenario. Officially known as Representative Concentration Pathway or RCP 8.5, a label chosen because it represents an increase in energy of 8.5 watts per square meter at Earth's surface at the end of the century. To result in that level, it assumes little future change in emission reduction policies. It is not a true business-as-usual scenario, but is the closest to that of the four scenarios.[9] In Figure 2 below, the high scenario is represented by the blue lines.
- A **medium #1** scenario. Officially known as RCP 6.0, again based on the net energy change at the end of the century, it initially assumes the lowest emissions levels of all scenarios but then sharp increases. From the 2060s to the end of the century, it assumes the second highest atmospheric concentrations of heat-trapping gases. It is represented by the black lines in Figure 2.
- A **medium #2** scenario, or RCP 4.5. It starts out with higher emissions than medium #1 but then has major reductions after mid-century, as shown by the red lines in Figure 2.
- A **low** scenario, RCP 2.6. It assumes emissions cuts of more than 70 percent from current levels by 2050 and an elimination of net human emissions by about 2080. This likely would keep the average global temperature increase under 3.6° (2° Celsius) compared to pre-industrial levels, but not enough to achieve the official international goal of keeping it "well below" 3.6°, preferably to 2.7° (1.5° C).[10] The low scenario is represented by the green lines in Figure 2.

Scenarios of Future Heat-Trapping Emissions



A. Annual Emissions of Carbon Dioxide

B. Atmospheric Concentrations of Carbon Dioxide

C. Radiative Forcing

Figure 2. Key values for the emissions scenarios used in this analysis: A, annual global emissions of carbon dioxide in gigatons of carbon; B, atmospheric concentrations of carbon dioxide, in parts per million; and C, radiative forcing, or the average warming at Earth's surface resulting from heat-trapping pollution, in watts per square meter. In all three parts of the figure, the blue lines represent the scenario identified as "high" in this report; the black lines, "medium #1"; the red lines, "medium #2"; and the green lines, "low." Figures provided by D. van Vuuren.[11]

No scenario is believed to be more likely than the others—instead, they were chosen to illustrate the range of plausible futures. Actual global emission levels in recent years have been lower than the high scenario's pathway, but closer to it than to any other scenario.[12] Which scenario turns out closest to reality depends on future public and private actions. (For more on the scenarios, see pages 47–48.)

Climate models

The climate projections used in this analysis were obtained by RMCO from an online archive created by the U.S. Bureau of Reclamation and other institutions.[13] The projections are from the generation of climate models, known as CMIP5 models, that are the latest models have been downscaled to produce local projections. (For details, see pages 47–48.)

The climate projections obtained and analyzed for this report are of daily maximum and minimum temperatures and precipitation amounts for every day from 2020 through 2099, compared to actual observations for a baseline period of 1970–1999 (see page 47). One projection was obtained from each of the available models using the different emission scenarios—20 climate models for the high scenario, 12 for medium #1, 19 for medium #2, and 16 for the low scenario. In all, for this report more than 24 million individual projections of future weather were analyzed, covering the three weather values, 110 years, 67 pairings of climate models and emission scenarios, and the three separate grids.

In presenting results from each pairing of climate models and emission scenario, we report both the median of all relevant projections as well as the range from the 10th percentile to the 90th percentile of the projections—setting aside the lowest and highest values, as illustrated by Figure 3 below for the subsequent figures used in this report. As an example of how this is represented in text, the values shown by the sample column in Figure 3 below would be written as "20 (15–25)," with 20 being the median projection, 15 the 10th percentile, and 25 the 90th percentile.

How this report's figures represent the projections

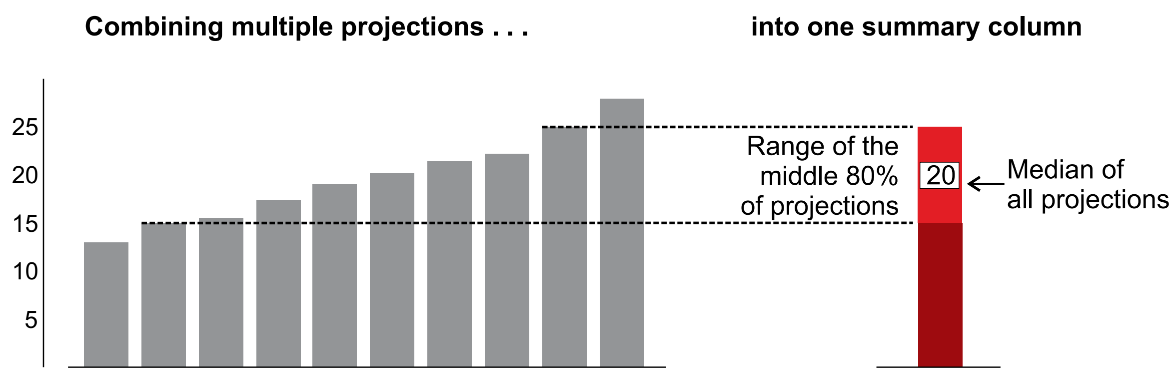


Figure 3. Illustration of how individual projections are represented in the figures on temperature projections on the following pages. On the left, of all projections (hypothetically here from 10 models), the middle 80 percent are combined into a single column (on the right), with that range shown by the lighter color of the upper portion of the column. Another way to express this is that the brighter portion of the column shows the range from the 10th percentile to the 90th percentile of all projections. The numeral in the column shows the median of all projections.

Ninety percent of the models project at least as much change as is represented by the dividing line between the brighter and the darker colors in a column. That line shows the 10th percentile of the projections—meaning that ten percent of the projections are below there, so ninety percent are above that level.

2. Future Temperatures

The model projections obtained for this report were analyzed to consider 74 different measures of how local temperatures may change, including 39 measures of high temperatures and 35 of lows. This report focuses just on the most telling of those projections, and for simplicity the text uses examples from only the high and low emission scenarios and primarily from the mid-century (2020–2039) and late century (2080–2099) time periods. The figures and tables throughout the report, though, cover all four emission levels and all four time periods. Spreadsheets with the results from the analysis of all 74 temperature values (as well as of all precipitation values) are available online at www.rockymountainclimte.org/extremes/summit.

The tables at the end of this section document the statements made here, unless another source is indicated.

Baseline temperature values (and baseline precipitation values in section 3) used as comparisons to the model projections are gridded observed values for 1970–1999. These are derived from records from weather stations that have been converted into averages for each grid (see page 47).

Average temperatures

To begin with, the **average annual high temperature** in, for example, the **Frisco/Dillon Reservoir grid** is projected with **high emissions** to increase by mid-century by 5° (3–7°)* and by late in the century by 9° (8–12°), compared to 1970–1999 (see the online data). Somewhat larger temperature increases are forecast for hotter months than for colder ones, by a margin of about 1–2° in mid-century, depending on the grid. For example, in the **Frisco/Dillon Reservoir** grid in mid-century, **temperatures in the hot months** (May through October) are projected to average 6° (5–8°) hotter than in the baseline years, and the **temperatures in the cold months** (November–April) are projected to be 4° (3–6°) warmer. In this case, that is about a two-degree difference. (Throughout this report when one grid is used as an example in text or figures, the other grids show similar patterns, as shown by the data in the appropriate tables.)

But what, exactly, does an increase of a few degrees in average temperature mean across a year or six months? To understand how daily life could be different for people living in and visiting Summit County, it helps to look at daily data. Analyzing millions of projections of hot and cold temperatures on individual days makes it possible to extract more vivid pictures of the possible futures before us.

Hotter summers

The most striking projections are for how much hotter Summit County summers could become unless heat-trapping emissions are sharply reduced.

The following two sets of examples are for the **Frisco/Dillon Reservoir grid** with **high emissions**. The tables at the end of this section show comparable values for the other grids.

The **hottest days of the year** in the grid are projected:

- In typical mid-century years, to average 85° (83–87°)—compared to 79° in 1970–1999.
- In the extreme year in mid-century, to be 88° (85–90°)—compared to 82°, the highest temperature in 1970–1999.
- In typical late-century years, to average 90° (88–94°).
- In the extreme year in late century, to get as hot as 94° (91–98°).

In the Frisco/Dillon Reservoir grid, an *average* summer day in mid-century could be three degrees hotter than the single hottest day of the late 20th century.

*Here, 5° is the median projection, 3° is the 10th percentile, and 7° is the 90th percentile (see the previous page).

Note that, because their elevations are lower than the grid's average elevation, Frisco and other communities around Dillon Reservoir could be expected to have temperatures about 3° hotter than the above projections, and Breckenridge could be expected to be about 1° hotter (see pages 5–6).

Even more telling might be how much more common hot days could become. Also in the **Frisco/Dillon Reservoir grid** with **high emissions**, **days 80° and hotter** per year are projected:

- In typical mid-century years, to average 12 (6–27) days. That median projection is for a thirty-fold increase over the baseline years, which averaged 0.4 day per year.
- In the extreme year in mid-century, to be 37 (20–55) days. That median projection is more than a full month's worth. By contrast, the highest number in 1970–1999 was four such days.
- In typical years late in the century, to average 54 (38–86) days. That median projection, nearly two months's worth.
- In the extreme year late in the century, to occur 89 (74–115) times. That median projection, a full summer's worth.

Again, because their elevations are lower than the grid's average elevation, for Frisco and other communities around Dillon Reservoir (around 9,000 feet in elevation), the above projected number of days per year would correspond to about that many days 83° and hotter, instead of 80° and hotter. For Breckenridge, the above projections would correspond to days 81° and hotter. (See pages 5–6).

Following are the corresponding projections for the **Breckenridge-Quandary grid** (at a significantly higher elevation, and so with a much cooler climate), also with **high emissions**.

The **hottest days of the year** are projected:

- In typical mid-century years, to average 80° (78–82°), compared to 74° in 1970–1999..
- In the extreme year in mid-century, to be 86° (84–89°), compared to 80°in 1970–1999.
- In typical late-century years, to average 85° (83–89°).
- In the extreme year in late century, to get up to 91° (89–95°).

Days 75° and hotter per year are projected:

- In typical mid-century years, to average seven (4–20) days, compared to 0.6 day per year in the baseline period.
- In the extreme mid-century year, to number 31 (19–51) days, compared to seven in the hottest baseline year.
- In typical years late in the century, to average 42 (26–79) such days.
- In the extreme year late in the century, to occur 80 (62–111) times.

Caveat: Projected high temperatures could be higher

It is worth pointing out that the climate models appear not to actually capture how hot the future extremes could be, as the federal government's climate science programs says in the following quote. So the values stated here for future hot days and extreme years could well be underestimated.

> "Climate models are more likely to underestimate than to overestimate the amount of long-term future change; this is likely to be especially true for trends in extreme events."
>
> *U.S. Global Change Research Program*[14]

Comparison to summer 2021

The summer of 2021 has been hot enough to prompt the question, how does this summer compare to the projections for typical years and the extreme year for the period 2020–2039, which has just begun? Data from the Dillon weather station described on pages 5–6 offers the best comparison. Reducing the station's recorded daily high temperatures by 3° to compensate for its lower elevation and higher temperatures than the averages for the grid (see pages 5–6) produces approximate average values for the grid. Allowing for that 3° difference, the station's records for summer (June–August) 2021[15] are very close to the median projections with high emissions for conditions averaged across the grid for a typical year in 2020–2039. Key comparisons are:

- The average high temperature at the weather station in summer 2021 was 74°, which would correspond to a 71° average across the grid—one degree shy of the 72° projected for a typical year's average high temperature across the grid in 2020–2039.
- The station's hottest temperature for the year was 85°, arguably corresponding to a grid-average high of 82°—or one degree below the 83° projected for a typical year's hottest day across the grid in 2020–2039.
- The station's daily high reached 83° or hotter six times in 2021, corresponding to that many days 80° or hotter across the grid—or two more than the four 80°-plus days projected for a typical 2020–2039 year.

Compared instead to the *extreme* year projected with high emissions in the 2020–2039 period, the summer of 2021 fell short:

- The 85° temperature of the hottest day of 2021 at the weather station would correspond to an 82° hottest day across the grid—four degrees short of the 86° projected for the extreme year in that period.
- The six 83°-plus days at the weather station in 2021 would correspond to that number of 80°-plus days—nine fewer than the fifteen such days projected for the extreme year.

This suggests that the summer of 2021 in this grid resembles a typical 2020–2039 year—but is not close to the hottest year projected to occur in that period.

Sharp emission reductions halt temperature changes

There is good news, too, from this analysis. The most important is that it shows how completely the above changes can be avoided if global emissions of heat-trapping pollution are sharply reduced. The following examples also are for the **Frisco/Dillon Reservoir** grid, but now with the scenario of low emissions.

With **low future emissions**, the **hottest days of the year** are projected:

- In 2020–2039 in typical years, to average 82° (81–83°)—about three degrees higher than in the baseline.
- Then to remain essentially the same for the rest of the century—in 2040–2059, 83° (81–84°); in 2060–2079, 82° (81–84°); and late in the century, again 82° (81–84°).

Also with **low emissions**, **days 80° and hotter** are projected:

- In 2020–2039 in typical years, to average 3 (1–5) such days per year.
- To remain essentially the same thereafter: in mid-century, 3 (1–7) such days; in 2060–2079, 3 (1–6); and in 2020–2039, again 3 (1–7) such days.

These examples show, as do all other data in the figures and tables in this section, that with the low emission scenario, the period 2020–2039 will have higher temperatures than the recent past, but after then essentially no further temperature increases are projected for later in the century.

Figure 4 on the next page shows projections for the hottest days in the Frisco/Dillon Reservoir grid in typical years for each 20-year period. Figure 5 on the following page shows projections for the number of 80°-plus days in the same grid for typical years, and Figure 6 on page 14 shows the number of projected 80°-plus days in the gird in extreme years (the single hottest years) in those 20-year periods.

If global emissions are brought down to low levels, essentially no further temperature increases are projected for later in the century beyond those that could occur in 2020–2039.

Hottest day of the year in the Frisco/Dillon Reservoir grid
Typical years: Averages for each 20-year period

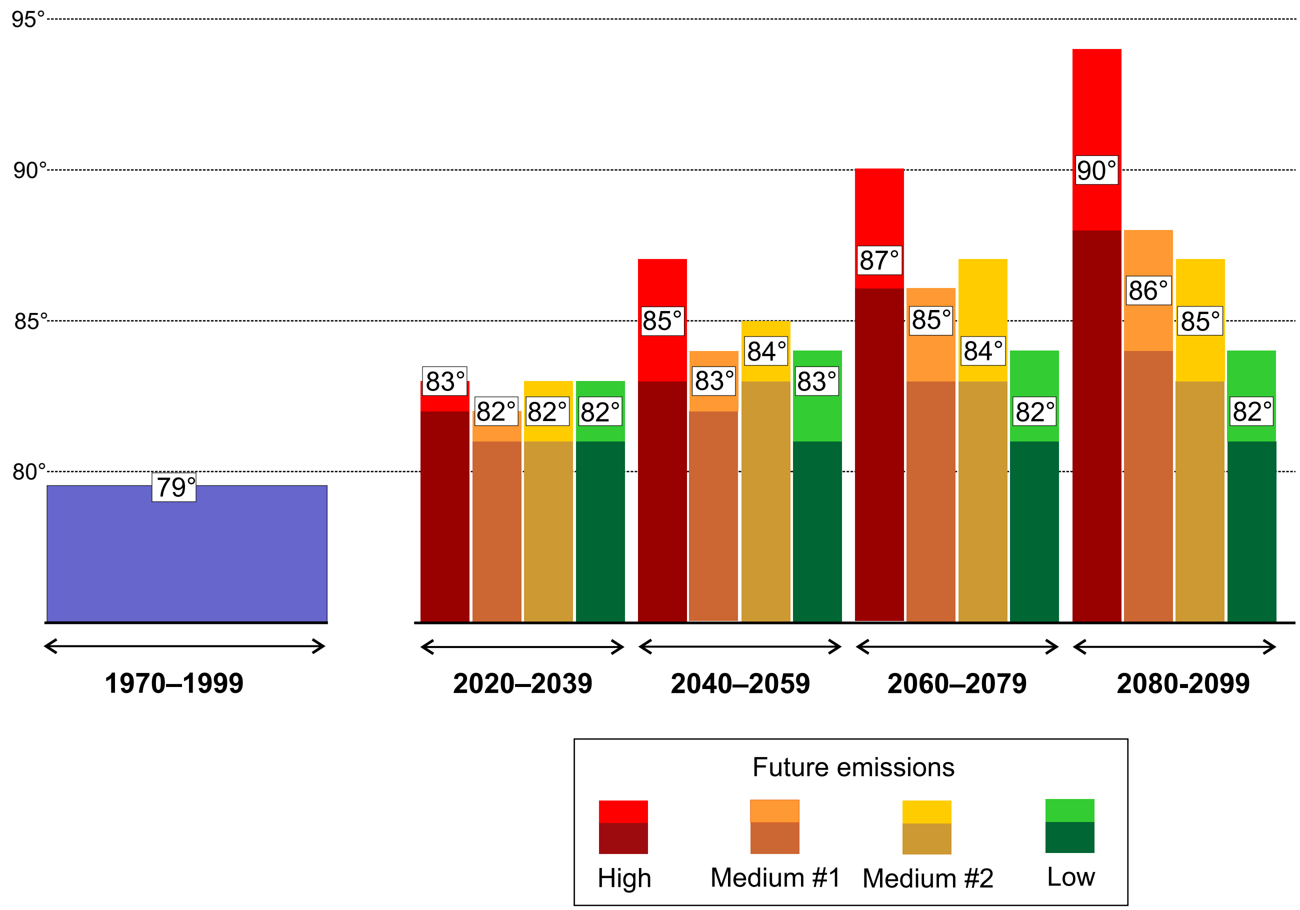


Figure 4. Observations and projections for the highest daily high temperature of the year, averaged across the Frisco/Dillon Reservoir grid for the indicated time periods. Observations for the 1970–1999 baseline period are from observed/gridded data (see page 480). For each future period, the four columns represent different projections based on the emission scenarios identified on page 7. For each such column, the brighter color on the top of the column shows the range of the middle 80 percent of the projections (from the 10th percentile to the 90th percentile); the numerals are the medians, as illustrated in Figure 3 on page 8. For the data illustrated here, see tables 1 and 2 on pages 21 and 22.

In the Frisco/Dillon Reservoir grid, an *average* summer day in mid-century could be three degrees hotter than the single hottest day of the late 20th century, which was 82° (see Table 1 on page 21).

Days 80° or hotter in the Frisco/Dillon Reservoir grid
Typical years: Averages for each 20-year period

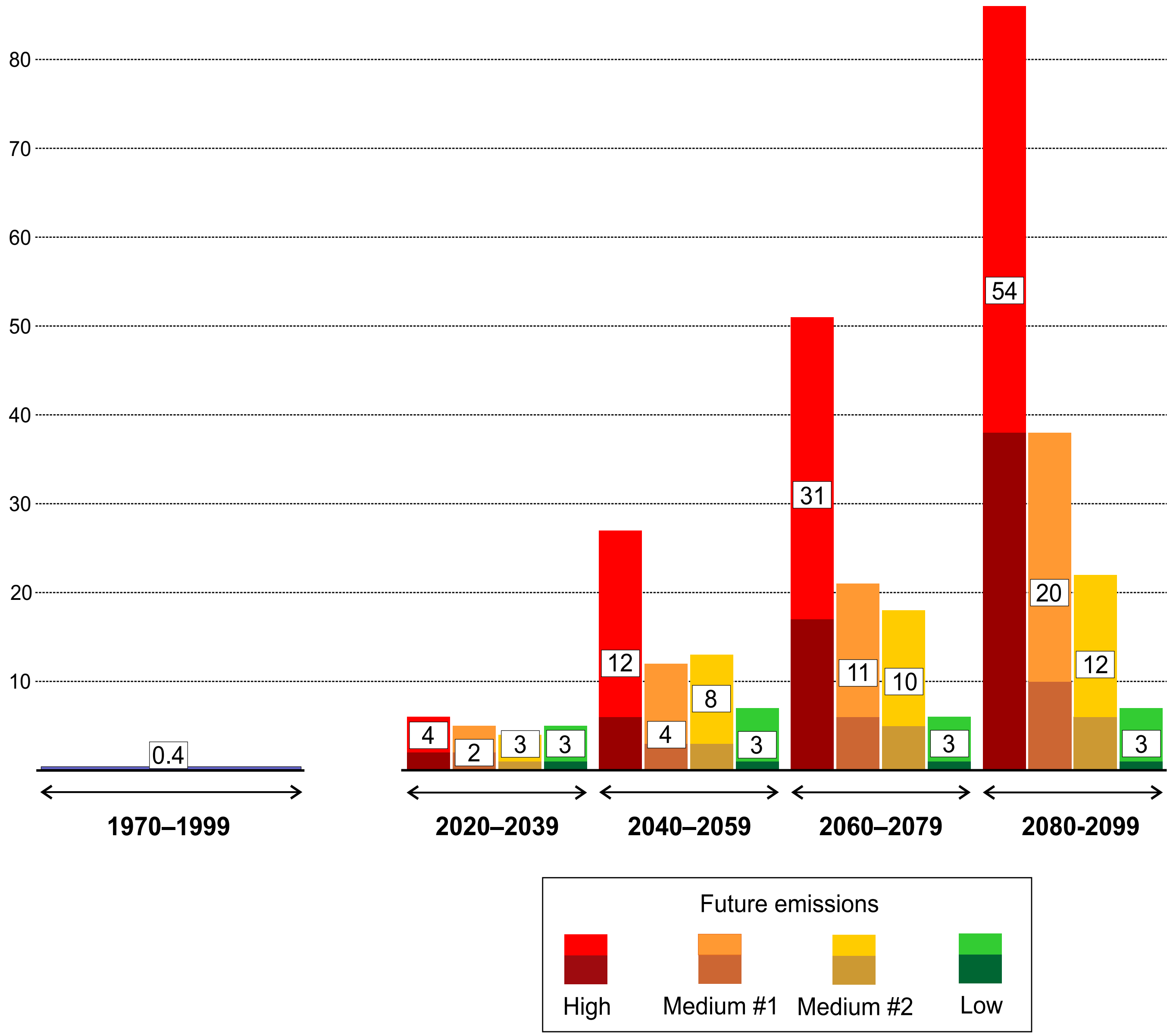


Figure 5. As Figure 4 on the previous page, but for the number of days per year with high temperatures (averaged across the grid) of 80° or higher.

The four emission scenarios illustrate possible futures. Which one turns out to be closest to reality depends on future public and private actions.

In a future with continued high emissions, the Frisco/Dillon Reservoir grid in mid-century could average twelve 80°-plus days a year— compared to 0.4 per year in the recent past. Late in the century, the average could be 54 days.

Days 80° or hotter in the Frisco/Dillon Reservoir grid
Extremes: The hottest year in each 20-year period

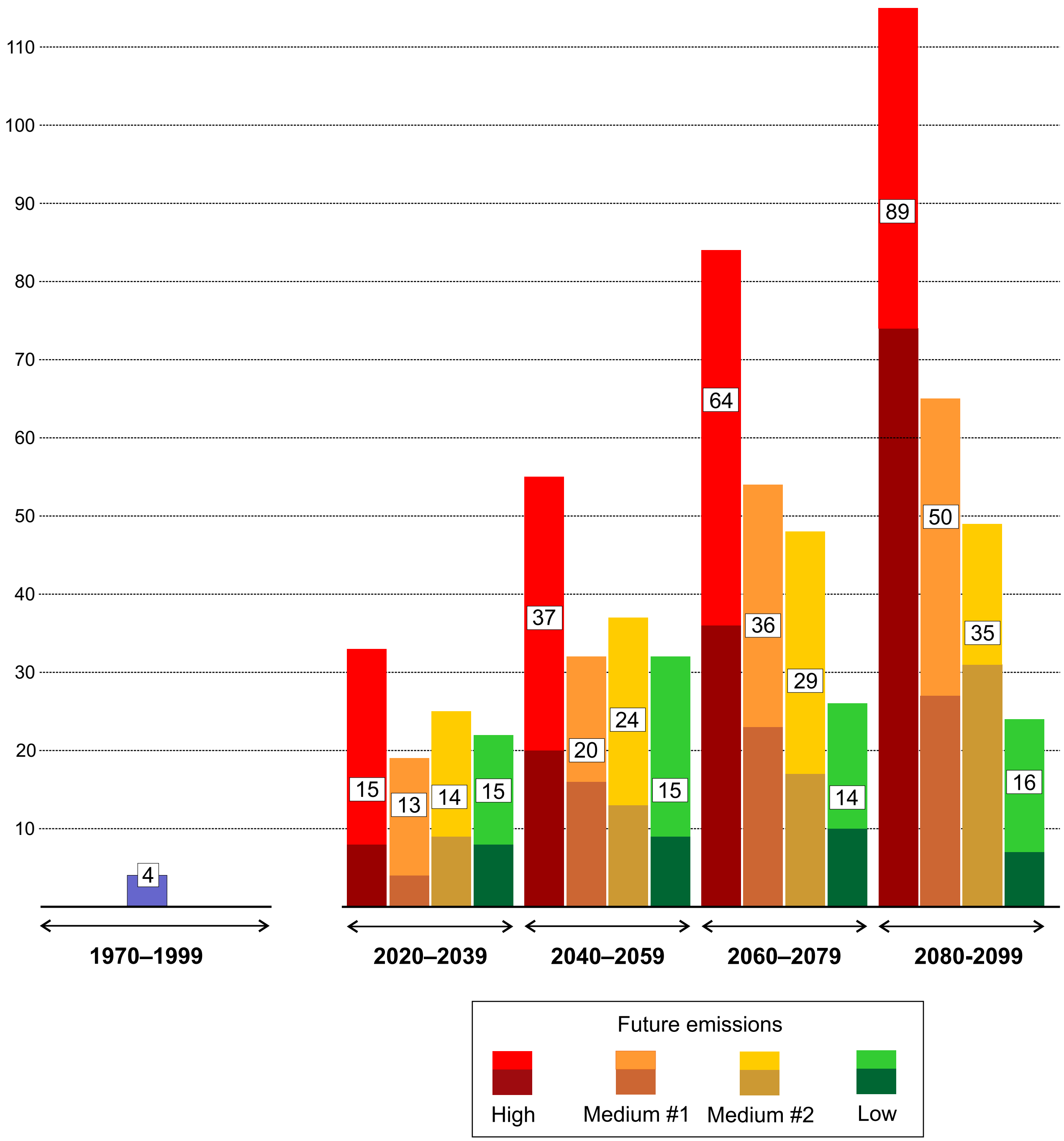


Figure 6. As Figure 5 on the previous page, but for the hottest individual year in each period—on the left, the highest number of 80°-plus days in 1970–1999, and on the right the highest projected number of such days in each of the 20-year periods. For the data illustrated here, see tables 1 and 2 on pages 20 and 21.

With high emissions, the hottest year in mid-century could have more than a month's worth of days 80° or hotter, and late in the century a whole summer's worth.

With low emissions, the hottest year in each period could stay about the same.

The other two Summit County areas, the **Breckenridge/Quandary and Vail Pass/North Tenmile Creek grids**, are at higher elevations, where 80° days are historically unknown and begin to appear in the projections only in extreme years after mid-century. The figures below and on the next page illustrate instead the number of days 75° and hotter in the Breckenridge/Quandary grid.

Days 75° or hotter in the Breckenridge/Quandary grid
Typical years: The average year in each 20-year period

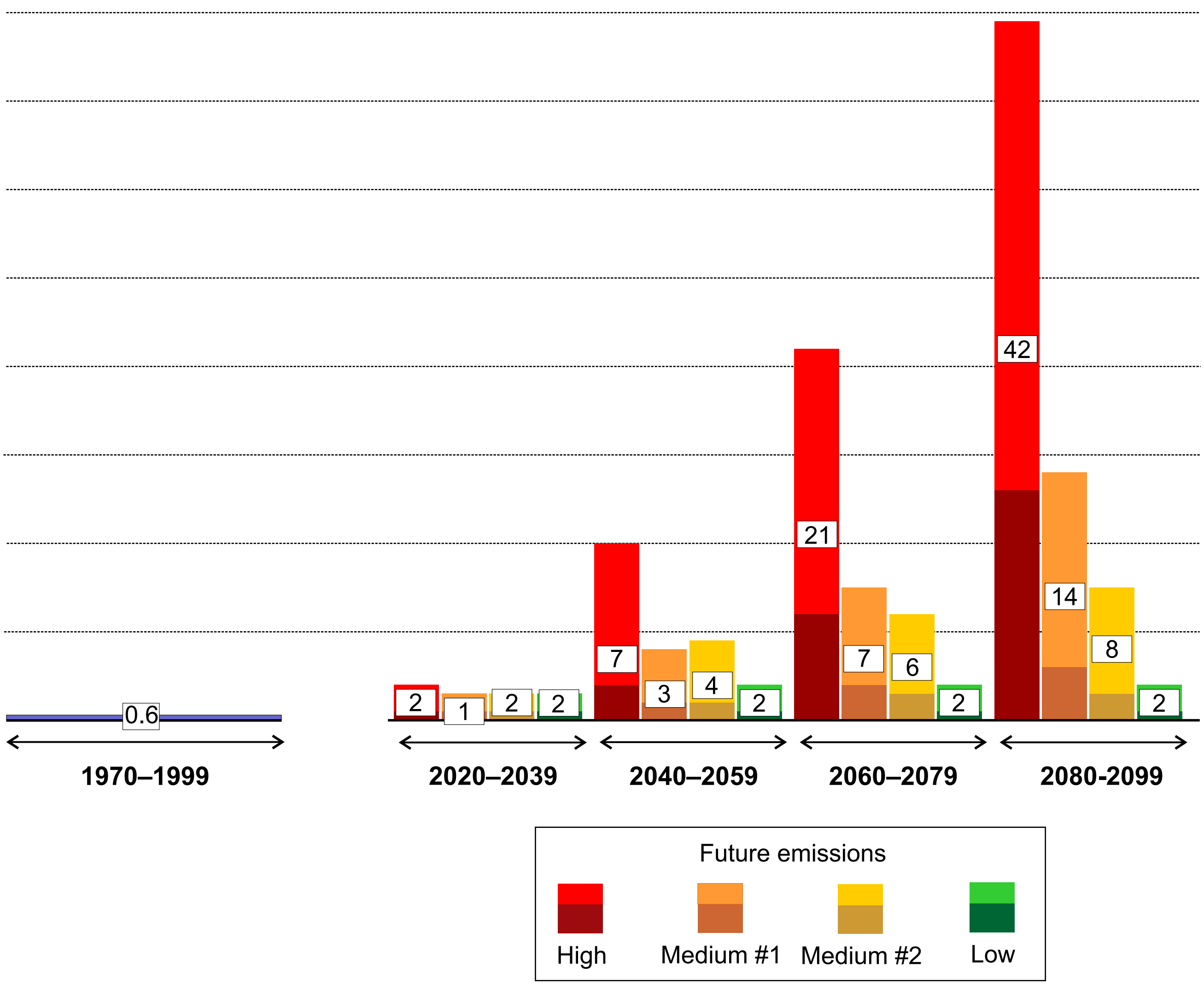


Figure 7. As figure 5 on page 13, but for days 75° and hotter in the Breckenridge/Quandary grid. For the data illustrated here, see tables 3 and 4 on pages 23 and 24.

The Breckenridge/Quandary grid, similar in elevation to the Vail Pass/North Tenmile Creek grid, has similar projections for future 75°-plus days.

Days 75° or hotter in the Breckenridge/Quandary grid
Extremes: The hottest year in each 20-year period

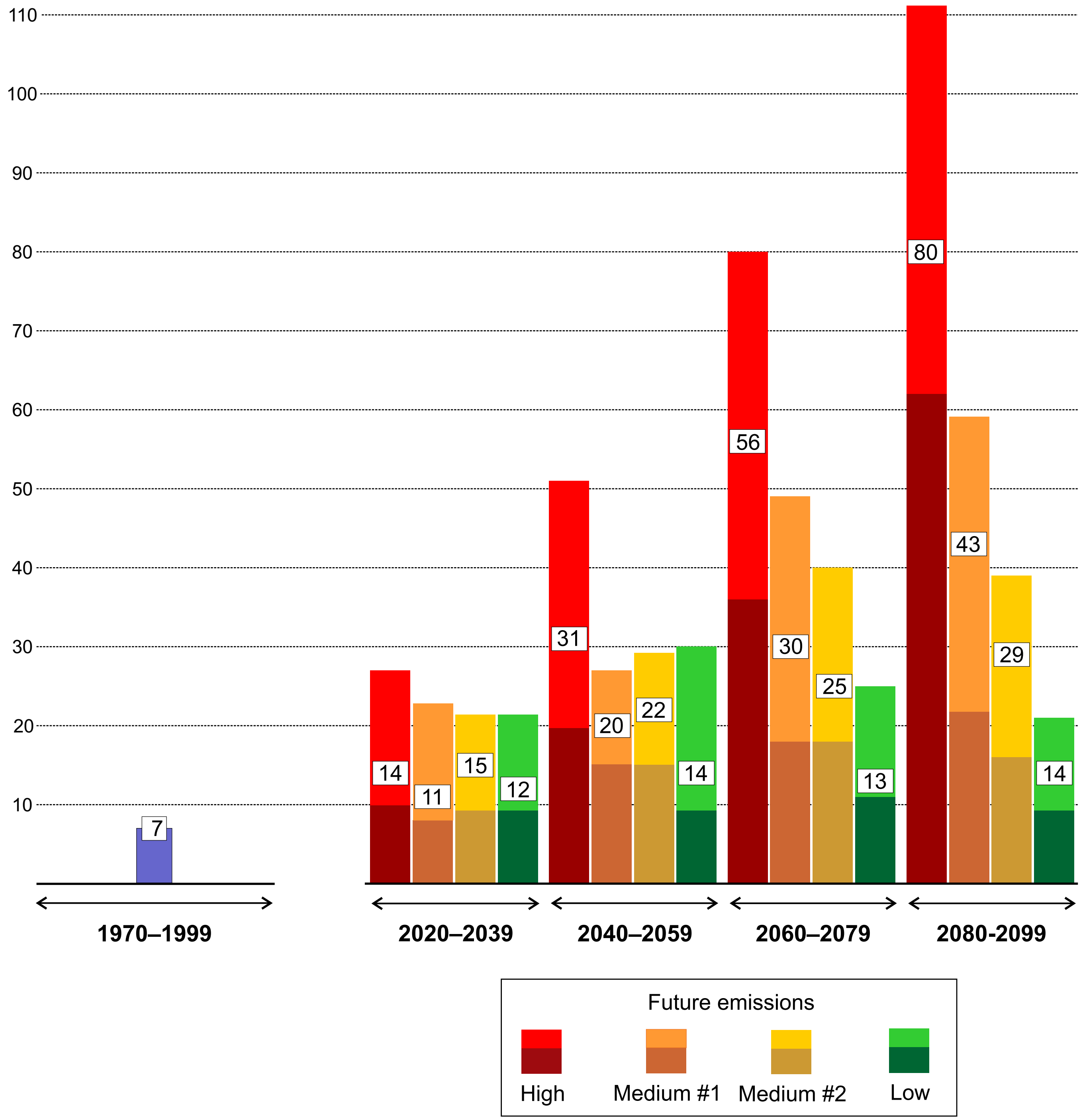


Figure 8. As figure 6 on page 14, but for days 75° and hotter in the Breckenridge/Quandary grid. For the data illustrated here, see tables 3 and 4 on pages 23 and 24.

Warmer winters

Winters are also projected to get warmer. This analysis considered temperatures from November 15 of one year to April 15 of the next, chosen to approximate the core season for both snowpack accumulation and skiing and other snow-dependent sports. The examples on this page are for the **Breckenridge/Quandary grid** (including the Breckenridge Ski Resort) with **high emissions**.

High temperatures above freezing.—The number of days with highs above 32° in the November 15 through April 15 stretch (which is 152 days long, or 153 in leap years) are projected:

- In typical years in mid-century, to average 54 (48–64 percent) of those days (or a count of 82 (74–98) days). That compares to an average of 38 percent in 1970–1999.
- In the extreme year in mid-century, to be 70 (57–78) percent of those days—compared to a high of 52 percent in the baseline period.
- In typical years late in the century, to average 71 (61–79) percent of those days.
- In the extreme year late in the century, to be 81 (66–88) percent of the days.

Figure 9 on the following page illustrates these projections.

On the other hand, some other good news: Over the same snow/skiing season, no nights are projected to have low temperatures above freezing, even in extreme years late in the century.

With high emissions, temperatures above freezing could occur in twice as many days in the snow/ski season in typical mid-century years, compared to 1970–1999.

Earlier spring warm-up

Days in late winter and early spring are also projected to warm up earlier. As winter turns to spring, days appreciably above freezing start melting snowpacks and turning ski slopes slushy. As a measure of changes in this transition, the projected number of days 40° or hotter, warm enough to cause snowmelt and slushy skiing, were analyzed for the stretch of March 16 through April 15, chosen to represent the last month of the core snow/skiing season. In the **Breckenridge/Quandary grid** with high emissions, the percentage of **40°-plus days** in that 31-day stretch is projected:

- In mid-century in typical years, to average 48 (41–55) percent of those days—compared to 30 percent in 1970–1999.
- In mid-century in the extreme year, to be 73 (57–84) percent of those days—compared to 55 percent, the high number in 1970–1999.
- Late in the century in typical years, to average 63 (53–80) percent.
- Late in the century in the extreme year, to be 79 (67–94) percent of those days.

The first month of the core snow/skiing season, by contrast, does not have as many 40°-plus days to begin with, nor a similar projected growth in such days. For instance, 40°-plus days in the Breckenridge/Quandary grid in November 15 through December 14 with high emissions are projected to average seven (6–10) such days in typical mid-century years, compared to four such days in the baseline period (see the online data). This and related data posted online suggests that temperature changes may be more likely to have an effect at the end of the snow/skiing season than at the beginning.

Percent of Nov 15-Apr 15 days w/ highs above 32° in Breckenridge/Quandary grid
Typical years: The average year in each 20-year period

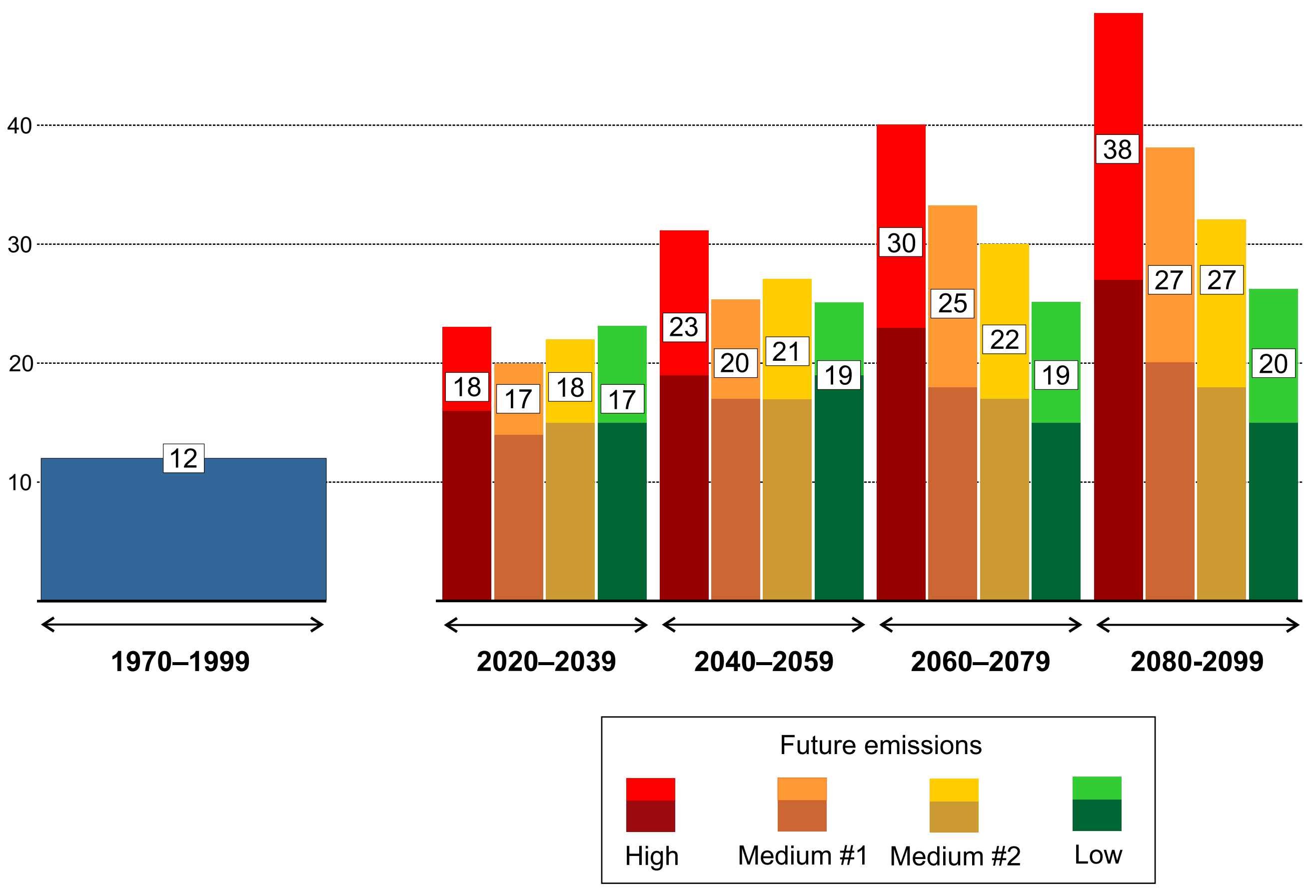


Figure 9. As figure 5 on page 13, but for days 32° and hotter from November 15 of one year through April 15 of the following year in the Breckenridge/Quandary grid. The number of days in that stretch is 143 (144 in leap years), and the actual average number of days in 1970–1999 was 57. For the data illustrated here, see tables 3 and 4 on pages 23 and 243. (In those tables, the data shown above are presented as the *number* of such days in the stretch of November 15 through April 15; the figure above instead shows the data as the *percentage* of such days in that stretch.)

With high emissions, the percentage of days in the core snow/skiing season that get above freezing in the Breckenridge/Quandary grid could double by mid-century and triple by late in the century.

Percent of Nov 15-Apr 15 days w/ highs above 32° in Breckenridge/Quandary grid
***Extremes:* The hottest year in each 20-year period**

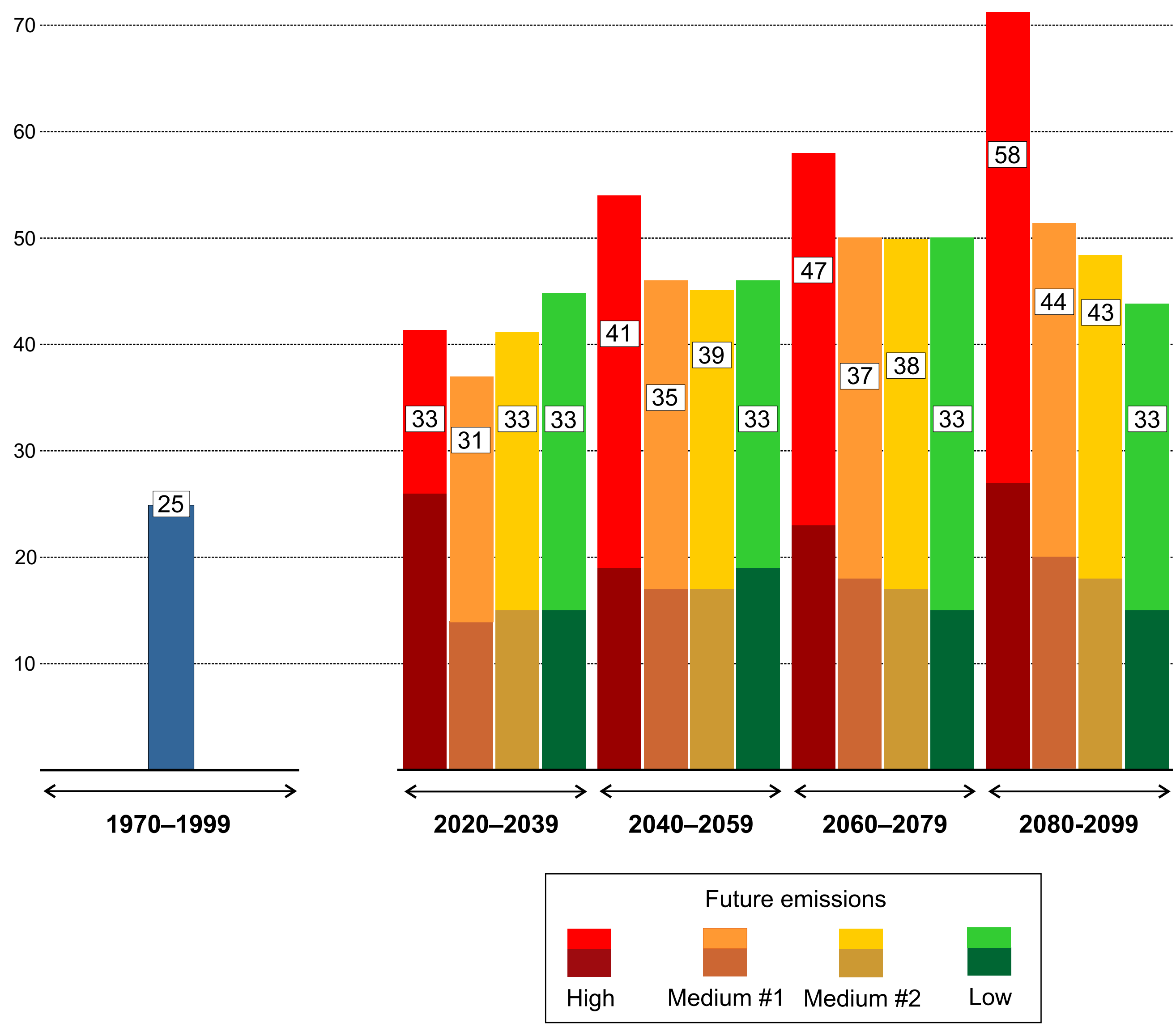


Figure 10. As Figure 9 on the previous page, but for the hottest individual year in each period—on the left, the highest percentage of days above 32° of any single year in 1970–1999, and on the right the highest projected percentage for any single year in each 20-year period. For the data illustrated here, see tables 3 and 4 on pages 23 and 24.

With low emissions, in the hottest year in the 2020–2039 period, one third of days in the core snow/skiing season could get above freezing in the Breckenridge/Quandary grid. That would be higher than in the recent past, but the number could stay at one third of the days even in the hottest years over the rest of the century.

Tables of High Temperature Projections

Tables 1 through 6 that follow (through page 26) present key results of the analysis of the climate models's projections of future high temperatures. After those, tables 7 through 12 (on pages 27–32) do the same for low temperatures. The tables are in pairs, with the first of each pair showing projections for the first two 20-year periods (2020–2039 and 2040–2059) for a particular grid and the next table showing projections for the two subsequent periods.

Full results from the analysis of all 74 temperature values considered in this project can be found at www.rockymountainclimate.org/extremes/summit.

High temperatures in Frisco/Dillon Reservoir grid, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg high (Nov thru Apr), change	35°	+3° (+1/+4°)	+2° (+1/+3°)	+3° (+1/+4°)	+2° (+2/+4°)	+4° (+3/+6°)	+3° (+2/+5°)	+3° (+2/+5°)	+3° (+2/+4°)
Hot months avg high (May thru Oct), change	53°	+4° (+2/+5°)	+3° (+2/+4°)	+4° (+2/+4°)	+3° (+2/+4°)	+6° (+5/+8°)	+4° (+4/+5°)	+5° (+3/+6°)	+4° (+2/+5°)
Average high in Jun-Jul-Aug	68°	72° (71–73°)	71° (70–72°)	72° (70–72°)	72° (70–73°)	74° (73–76°)	72° (71–73°)	73° (71–74°)	72° (70–73°)
Days per year 75° or hotter	9	34 (25–45)	28 (21–32)	32 (22–40)	32 (24–40)	57 (45–73)	40 (32–50)	45 (29–57)	34 (21–46)
Days per year 80° or hotter	0.4	4 (2–6)	2 (1–5)	3 (1–4)	3 (1–5)	12 (6–27)	4 (3–12)	8 (3–13)	3 (1–7)
High temp of year's hottest day	79°	83° (82–83°)	82° (81–82°)	82° (81–83°)	82° (81–83°)	85° (83–87°)	83° (82–84°)	84° (83–85°)	83° (81–84°)
Days/yr Nov 15–Apr 15 32° or hotter	84	97 (90–107)	94 (91–101)	98 (90–104)	98 (92–105)	106 (98–117)	101 (96–110)	104 (97–110)	98 (92–107)
Days/yr Mar 16–Apr 15 40° or hotter	14	18 (16–21)	18 (16–21)	17 (16–22)	18 (16–23)	19 (17–23)	18 (17–23)	19 (17–23)	19 (17–22)
Extreme years									
Average high in June-July-August	71°	74° (72–77°)	73° (72–75°)	74° (72–76°)	74° (72–75°)	77° (74–79°)	75° (73–77°)	75° (74–77°)	74° (72–77°)
Days per year 75° or hotter	20	55 (38–73)	53 (31–63)	52 (39–61)	53 (38–62)	79 (62–91)	64 (46–77)	63 (49–81)	50 (36–69)
Days per year 80° or hotter	4	15 (8–33)	13 (4–19)	14 (9–25)	15 (8–22)	37 (20–55)	20 (16–32)	24 (13–36)	15 (9–32)
High temp of year's hottest day	82°	86° (84–88°)	84° (83–86°)	85° (82–88°)	84° (83–86°)	88° (85–90°)	86° (84–87°)	87° (84–89°)	86° (84–88°)
Days/yr Nov 15–Apr 15 32° or hotter	107	121 (109–131)	116 (107–130)	116 (107–130)	120 (109–130)	129 (114–136)	122 (108–132)	124 (109-132)	120 (111-131)
Days/yr Mar 16–Apr 15 40° or hotter	23	25 (23–27)	24 (20–26)	25 (21–28)	25 (22–29)	25 (22–28)	24 (22–27)	24 (22–29)	25 (23–27)

Table 1. For 1970–1999, the actual values for the grid are from observed/gridded data (see page 47); the first two rows show changes from these values, and the other rows show projected future absolute values. The projections are for the four emission scenarios identified on page 7. Values for typical years are annual averages for the 20 years in each time period. Values for extreme years are the highest projected values in each period. For the projections, the top row shows the median of the projections from all climate models for that emissions scenario, and the next row shows in parentheses the 10th percentile of the projections and the 90th percentile—in other words, the range of the middle 80 percent of those projections (see page 8).

High temperatures in Frisco/Dillon Reservoir grid, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels: 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg high (Nov thru Apr), change	35°	+6° (+4/+9°)	+4° (+3/+7°)	+4° (+2/+6°)	+2° (+2/+4°)	+8° (+6/+11°)	+6° (+4/+8°)	+5° (+3/+7°)	+2° (+2/+5°)
Hot months avg high (May thru Oct), change	53°	+8° (+7/+11°)	+6° (+4/+7°)	+6° (+4/+7°)	+4° (+2/+5°)	+11° (+9/+15°)	+7° (+6/+9°)	+6° (+4/+8°)	+3° (+2/+5°)
Average high in Jun-Jul-Aug	68°	76° (75–79°)	74° (72–76°)	74° (72–75°)	71° (70–73°)	79 (77–84°)	75° (74–78°)	74° (72–76°)	71° (70–73°)
Days per year 75° or hotter	9	80 (68–99)	56 (40–74)	55 (37–71)	31 (20–48)	99 (88–120)	68 (54–90)	54 (42–76)	31 (22–48)
Days per year 80° or hotter	0.4	31 (17–51)	11 (6–21)	10 (5–18)	3 (1–6)	54 (38–86)	20 (10–38)	12 (6–22)	3 (1–7)
High temp of year's hottest day	79°	87° (86–90°)	85° (83–86°)	84° (83–86°)	82° (81–84°)	90° (88–94°)	86° (84–88°)	85° (83–87°)	82° (81–84°)
Days/yr Nov 15–Apr 15 32° or hotter	84	114 (107–125)	107 (102–118)	108 (97–116)	99 (94–107)	124 (113–132)	112 (105–125)	106 (97–118)	99 (92–111)
Days/yr Mar 16–Apr 15 40° or hotter	14	22 (19–26)	20 (17–27)	19 (16–25)	18 (16–23)	23 (20–27)	21 (20–27)	20 (17–24)	19 (16–24)
Extreme years									
Average high in June-July-August	71°	79° (77–83°)	76° (75–79°)	76° (73–78°)	74° (72–76°)	81° (79–86°)	78° (75–80°)	76° (75–79°)	74° (73–76°)
Days per year 75° or hotter	20	98 (82–112)	74 (63–97)	70 (54–83)	58 (37–71)	118 (91–143)	86 (68–105)	77 (55–94)	53 (35–66)
Days per year 80° or hotter	4	64 (37–84)	36 (23–54)	29 (17–48)	14 (10–26)	89 (74–115)	50 (27–65)	35 (21–49)	16 (7–24)
High temp of year's hottest day	82°	91° (88–93°)	88° (86–89°)	87° (85–90°)	85° (83–87°)	94° (91–98°)	90° (87–91°)	87° (84–91°)	85° (84–88°)
Days/yr Nov 15–Apr 15 32° or hotter	107	134 (120–140)	128 (123–136)	129 (112–134)	120 (113–126)	138 (126–146)	129 (123–138)	126 (114–134)	121 (108–127)
Days/yr Mar 16–Apr 15 40° or hotter	23	26 (23–29)	25 (22–26)	25 (22–27)	25 (22–28)	27 (24–30)	25 (24–28)	25 (21–28)	25 (22–28)

Table 2. As Table 1 on the previous page, but for the two later 20-year periods.

Sharply reducing emissions could keep temperatures from climbing any higher after the 2020–2021 period (shown in Table 1 on the previous page). With low future emissions, the hottest days of the year would stay at 82° or 83° in typical years, and at 84–86° in extreme years.

High temperatures in Breckenridge/Quandary grid, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg high (Nov thru Apr), change	30°	+3° (+2/+4°)	+2° (+1/+3°)	+3° (+1/+4°)	+2° (+2/+4°)	+4° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+5°)	+3° (+2/+4°)
Hot months avg high (May thru Oct), change	49°	+4° (+2/+5°)	+3° (+2/+4°)	+3° (+2/+4°)	+3° (+2/+4°)	+6° (+4/+8°)	+4° (+4/+5°	+5° (+3/+6°)	+4° (+2/+5°)
Average high in Jun-Jul-Aug	63°	66° (65–68°)	66° (65–66°)	66° (65–67°)	66° (65–67°)	68° (67–70°)	67° (66–68°)	67° (66–69°)	66° (65–68°)
Days per year 70° or hotter	9	27 (21–36)	23 (18–27)	26 (17–33)	26 (20–32)	49 (37–64)	33 (28–43)	38 (25–48)	28 (17–37)
Days per year 75° or hotter	0.6	2 (1–4)	1 (1–3)	2 (1–3)	2 (1–3)	7 (4–20)	3 (2–8)	4 (2–9)	2 (1–4)
High temp of year's hottest day	74°	78° (77–79°)	77° (76–78°)	77° (76–78°)	77° (76–78°)	80° (78–82°)	79° (78–80°)	79° (78–80°)	78° (76–79°)
Days/yr Nov 15–Apr 15 32° or hotter	58	72 (65–83)	69 (65–76)	72 (66–79)	72 (68–80)	82 (74–98)	76 (68–85)	79 (71–87)	74 (67–84)
Days/yr Mar 16–Apr 15 40° or hotter	9	13 (12–17)	13 (11–16)	13 (11–18)	13 (11–18)	15 (13–20)	13 (12–18)	15 (12–19)	14 (11–19)
Extreme years									
Average high temp in June-July-August	66°	70° (67–72°)	69° (67–70°)	70° (68–71°)	69° (68–70°)	72° (70–74°)	70° (69–72°)	71° (68–73°)	69° (68–72°)
Days per year 75° or hotter	7	14 (10–27)	11 (8–20)	15 (9–22)	12 (9–21)	31 (19–51)	20 (15–27)	22 (15–29)	14 (9–30)
Days per year 80° or hotter	0.0	0 (0–1)	0 (0–1)	0 (0–1)	0 (0–1)	2 (0–8)	1 (0–3)	1 (0–3)	0 (0–2)
High temp of year's hottest day	80°	84° (81–86°)	83° (81–85°)	83° (81–86°)	83° (81–84°)	86° (84–89°)	85° (83–86°)	84° (82–88°)	84° (81–86°)
Days/yr Nov 15–Apr 15 32° or hotter	79	96 (84–108)	92 (84–106)	90 (74–102)	97 (84–107)	106 (87–119)	101 (83–112)	101 (81–112)	98 (85–106)
Days/yr Mar 16–Apr 15 40° or hotter	17	20 (16–25)	19 (16–23)	22 (15–25)	21 (16–28)	23 (18–26)	21 (16–24)	22 (17–28)	22 (17–27)

Table 3. As Table 1 on page 21, but instead for the Breckenridge/Quandary grid.

With high emissions, the number of 75°-plus days in the Breckenridge/Quandary area could go from nine per year to 49 per year in mid-century (as already illustrated in Figure 7 on page 15) and continue climbing thereafter, as shown in Table 4 on the next page.

High temperatures in Breckenridge/Quandary grid, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels: 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg high (Nov thru Apr), change	30°	+6° (+4/+9°)	+4° (+3/+6°)	+4° (+2/+6°)	+2° (+2/+4°)	+8° (+6/+11°)	+5° (+4/+8°)	+5° (+2/+7°)	+2° (+2/+5°)
Hot months avg high (May thru Oct), change	49°	+8° (+7/+10°)	+6° (+4/+7°)	+5° (+4/+7°)	+4° (+2/+5°)	+11° (+9/+14°)	+7° (+6/+9°)	+6° (+4/+8°)	+3° (+2/+5°)
Average high in Jun-Jul-Aug	63°	71° (69–74°)	69° (67–70°)	68° (66–70°)	66° (65–68°)	74 (72–78°)	70° (69–72°)	68° (67–71°)	66° (65–68°)
Days per year 70° or hotter	9	73 (59–92)	49 (33–68)	47 (30–62)	25 (17–39)	94 (82–115)	61 (47–84)	46 (35–66)	25 (18–38)
Days per year 75° or hotter	0.6	21 (12–42)	7 (4–15)	6 (3–12)	2 (1–4)	42 (26–79)	14 (6–28)	8 (3–15)	2 (1–4)
High temp of year's hottest day	74°	82° (81–85°)	80° (78–82°)	80° (78–81°)	77° (76–79°)	85° (83–89°)	81° (80–84°)	80° (78–82°)	77° (76–79°)
Days/yr Nov 15–Apr 15 32° or hotter	58	93 (82–109)	84 (76–97)	83 (70–95)	74 (68–84)	108 (92–120)	89 (75–106)	85 (72–98)	75 (66–87)
Days/yr Mar 16–Apr 15 40° or hotter	9	19 (14–23)	16 (13–24)	15 (12–21)	13 (11–19)	20 (16–25)	17 (15–24)	15 (12–21)	14 (11–21)
Extreme years									
Average high temp in June-July-August	66°	74° (72–78°)	72° (70–74°)	72° (69–74°)	70° (68–71°)	77° (75–81°)	73° (71–75°)	72° (70–74°)	69° (69–72°)
Days per year 75° or hotter	7	56 (36–80)	30 (18–49)	25 (18–40)	13 (11–25)	80 (62–111)	43 (22–59)	29 (16–39)	14 (9–21)
Days per year 80° or hotter	0.0	10 (4–30)	2 (0–12)	1 (0–5)	0 (0–2)	26 (9–65)	4 (1–17)	2 (0–4)	0 (0–2)
High temp of year's hottest day	80°	89° (86–92°)	86° (84–88°)	85° (83–88°)	83° (81–86°)	91° (89–95°)	88° (85–90°)	84° (83–89°)	83° (81–86°)
Days/yr Nov 15–Apr 15 32° or hotter	79	113 (96–126)	110 (98–121)	103 (89–118)	95 (86–106)	123 (100–135)	110 (102–124)	104 (90–113)	93 (82–106)
Days/yr Mar 16–Apr 15 40° or hotter	17	23 (19–27)	22 (18–28)	23 (20–28)	20 (17–25)	25 (21–29)	23 (19–29)	20 (14–26)	21 (17–25)

Table 4. As Table 3 on the previous page, but with projections for the last two 20-year periods of the century.

This table again shows that low emissions keep temperatures from continuing to climb. Here, the median projections for the hottest day of the year go from 77° in 2020–2039 and 78° in mid-century (see Table 3 on the previous page) then stay at 77° for the last two 20-year periods of the century.

High temperatures in Vail Pass/North Tenmile Creek grid, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels							
		2020–2039				2040–2059			
		High	Med. #1	Med. #2	Low	High	Med. #1	Med. #2	Low
Typical years									
Cold months avg high (Nov thru Apr), change	30°	+2° (+1/+4°)	+2° (+1/+3°)	+3° (+1/+4°)	+2° (+2/+4°)	+4° (+3/+6°)	+3° (+2/+5°)	+3° (+2/+5°)	+3° (+2/+4°)
Hot months avg high (May thru Oct), change	50°	+4° (+2/+5°)	+3° (+2/+4°)	+4° (+2/+4°)	+3° (+2/+4°)	+6° (+5/+8°)	+4° (+4/+5°)	+5° (+3/+6°)	+4° (+2/+5°)
Average high in Jun-Jul-Aug	64°	68° (67–69°)	67° (66–68°)	68° (66–69°)	68° (67–69°)	70° (69–72°)	69° (68–69°)	69° (67–70°)	68° (66–69°)
Days per year 70° or hotter	15	44 (34–55)	37 (30–42)	41 (30–51)	42 (34–50)	67 (55–82)	51 (41–61)	56 (38–67)	44 (30–56)
Days per year 75° or hotter	1	7 (3–9)	3 (2–8)	5 (3–8)	5 (3–8)	17 (9–34)	8 (6–17)	12 (5–18)	5 (2–10)
High temp of year's hottest day	75°	79° (78–80°)	78° (77–79°)	78° (77–79°)	79° (78–79°)	81° (79–83°)	80° (79–81°)	80° (79–81°)	79° (77–81°)
Days/yr Nov 15–Apr 15 32° or hotter	56	70 (63–81)	67 (63–74)	71 (64–76)	71 (65–78)	80 (70–94)	75 (65–83)	77 (67–85)	71 (65–82)
Days/yr Mar 16–Apr 15 40° or hotter	10	14 (12–18)	14 (11–17)	14 (12–19)	14 (12–19)	15 (14–20)	14 (13–19)	15 (13–20)	15 (12–19)
Extreme years									
Average high in June-July-August	67°	71° (68–73°)	69° (68–71°)	70° (68–72°)	70° (68–71°)	73° (71–75°)	71° (69–73°)	71° (70–74°)	70° (68–73°)
Days per year 75° or hotter	8	23 (16–45)	21 (12–27)	22 (13–34)	22 (13–30)	47 (33–65)	31 (22–43)	35 (19–46)	23 (16–41)
Days per year 80° or hotter	0.0	1 (0–4)	0 (0–2)	0 (0–2)	0 (0–4)	5 (2–19)	2 (1–5)	2 (1–5)	1 (0–5)
High temp of year's hottest day	79°	83° (80–85°)	81° (79–84°)	82° (79–84°)	81° (80–83°)	85° (82–87°)	83° (82–85°)	84° (81–86°)	82° (80–85°)
Days/yr Nov 15–Apr 15 32° or hotter	84	100 (90–109)	95 (87–112)	96 (79–110)	99 (88–110)	108 (86–123)	105 (89–118)	107 (95–117)	102 (85–112)
Days/yr Mar 16–Apr 15 40° or hotter	20	22 (20–27)	23 (17–27)	24 (18–27)	24 (19–30)	24 (21–28)	23 (19–26)	25 (20–29)	24 (19–29)

Table 5. As Table 1 on page 21, but instead for the Vail Pass/Tenmile Creek grid.

Important for snowmelt, the number of 40°-plus days from mid-March through mid-April could increase with high emissions by 50 percent by mid-century, then continue increasing as shown in Table 6 on the next page.

High temperatures in Vail Pass/North Tenmile Creek grid, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg high (Nov thru Apr), change	30°	+6° (+4/+9°)	+4° (+3/+7°)	+4° (+2/+6°)	+2° (+2/+4°)	+8° (+6/+11°)	+6° (+4/+8°)	+5° (+2/+7°)	+2° (+2/+5°)
Hot months avg high (May thru Oct), change	50°	+8° (+7/+11°)	+6° (+4/+7°)	+6° (+4/+7°)	+4° (+2/+5°)	+11° (+9/+15°)	+7° (+6/+9°)	+6° (+4/+8°)	+3° (+2/+5°)
Average high in Jun-Jul-Aug	64°	72° (71–75°)	70° (68–72°)	70° (68–72°)	68° (66–69°)	70° (69–72°)	71° (70–74°)	69° (67–70°)	68° (66–69°)
Days per year 70° or hotter	15	88 (77–104)	66 (50–84)	65 (47–81)	41 (28–59)	106 (95–127)	77 (65–99)	64 (51–85)	41 (30–60)
Days per year 75° or hotter	1	39 (23–59)	17 (9–28)	15 (7–24)	5 (3–9)	63 (46–90)	27 (16–47)	17 (9–31)	5 (3–10)
High temp of year's hottest day	75°	83° (82–87°)	81° (80–83°)	81° (79–82°)	78° (77–80°)	86° (85–90°)	82° (81–84°)	81° (80–83°)	79° (77–81°)
Days/yr Nov 15–Apr 15 32° or hotter	56	90 (79–106)	82 (74–94)	81 (68–93)	72 (66–82)	103 (88–116)	87 (73–104)	83 (70–94)	73 (65–84)
Days/yr Mar 16–Apr 15 40° or hotter	10	19 (15–23)	16 (14–25)	16 (12–23)	14 (12–20)	20 (18–26)	18 (15–24)	17 (13–22)	15 (12–22)
Extreme years									
Average high temp in June-July-August	67°	75° (73–79°)	73° (71–75°)	72° (70–75°)	71° (68–72°)	78° (75–82°)	74° (72–76°)	73° (71–75°)	70° (69–72°)
Days per year 75° or hotter	8	74 (52–95)	49 (28–63)	39 (24–56)	21 (16–34)	98 (79–125)	58 (38–75)	48 (32–59)	24 (13–32)
Days per year 80° or hotter	0.0	18 (10–44)	4 (1–21)	5 (1–9)	1 (0–6)	46 (30–77)	13 (2–27)	5 (1–11)	1 (0–4)
High temp of year's hottest day	79°	87° (84–91°)	84° (83–86°)	84° (82–86°)	82° (80–84°)	91° (88–94°)	86° (84–89°)	84° (82–88°)	82° (81–85°)
Days/yr Nov 15–Apr 15 32° or hotter	84	118 (98–129)	112 (101–120)	109 (92–123)	98 (90–113)	127 (107–139)	115 (105–129)	111 (92–121)	97 (87–114)
Days/yr Mar 16–Apr 15 40° or hotter	20	26 (22–28)	25 (20–30)	25 (21–29)	24 (19–26)	27 (24–31)	25 (21–31)	24 (17–27)	23 (21–27)

Table 6. As Table 5 on the previous page, but with projections for the last two 20-year periods of the century.

By the end of the century with high emissions, the number of days above freezing in the snow season could nearly double, and the number of days above 40° from mid-March to mid-April could exactly double.

Tables of Low Temperature Projections

The table below and those that follow on the five pages follow present key results from the analysis of projected future low temperatures.

Low temperatures in Frisco/Dillon Reservoir grid, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	7°	+3° (+2/+3°)	+2° (+1/+3°)	+2° (+1/+3°)	+2° (+2/+4°)	+4° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+4°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	26°	+3° (2/+3)	+2° (+1/+3)	+2° (+1/+3)	+3° (+2/+3°)	+5° (+3/+6°)	+3° (+2/+4)	+3° (+2/+5°)	+3° (+2/+4)
Average low in Dec-Jan-Feb	2°	5° (3–5°)	4° (3–4°)	4° (3–5°)	4° (3–5°)	6° (5–7°)	5° (3–6°)	5° (4–6°)	5° (3–6°)
Low temp of year's coldest night	-24°	-21° (-22/-19°)	-22° (-24/-21°)	-22° (-23/-18°)	-21° (-23/-19°)	-19° (-21/-15°)	-20° (-22/-18°)	-20° (-22/-17°)	-20° (-23/-18°)
Low temp of year's warmest night	45°	48° (47–49°)	47° (46–48°)	47° (47–48°)	48° (47–49°)	50° (48–51°)	48° (47–49°)	49° (47–50°)	48° (47–49°)
Nights per year with lows above 32°	83	109 (99–113)	101 (96–109)	104 (97–111)	104 (98–112)	123 (113–133)	109 (99–118)	111 (100–125)	108 (99–119)
Nights Nov 15–Apr 15 with lows above 32°	0.0	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	47	33 (29–40)	39 (34–41)	34 (29–41)	35 (30–40)	26 (20–33)	29 (26–39)	30 (27–35)	35 (27–38)
May nights per year with lows above 32°	2	6 (4–7)	5 (4–6)	5 (4–7)	5 (4–6)	9 (7–12)	6 (4–7)	7 (5–10)	6 (4–8)
Days in frost-free growing season*	43	69 (52–76)	61 (53–74)	68 (54–73)	67 (56–77)	80 (64–97)	72 (59–84)	76 (61–89)	69 (55–83)
Extreme years									
Low temp of year's coldest night	-15°	-12° (-15°/-7°)	-13° (-17°/-9°)	-12° (-15°/11°)	-13° (-17°/-10°)	-10° (-13°/-6°)	-12° (-16°/-8°)	-13° (-15°/-6°)	-12° (-16°/-10°)
Low temp of year's warmest night	49°	51° (50–53°)	50° (49–51°)	51° (50–53°)	51° (50–52°)	53° (52–55°)	51° (51–53°)	52° (50–53°)	51° (49–53°)
May nights per year with lows above 32°	6	12 (9–18)	12 (7–15)	13 (9–16)	13 (8–15)	19 (14–22)	13 (11–17)	14 (10–21)	13 (10–19)

Table 7. As Table 1 on page 21, but with respect to daily low temperatures (typically occurring in the nighttime).

With high emissions, the Frisco/Dillon Reservoir area by mid-century could have about 40 more nights a year above freezing than in the baseline period.

*The frost-free growing season is the maximum number of consecutive days in a year with low temperatures above 32°.

Low temperatures in Frisco/Dillon Reservoir grid, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels 2060–2079 High	Med. #1	Med. #2	Low	2080–2099 High	Med. #1	Med. #2	Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	7°	+6° (+4/+8°)	+4° (+3/+6°)	+4° (+2/+5°)	+2° (+2/+4°)	+8° (+6/+10°)	+6° (+4/+8°)	+4° (+3/+6°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	26°	+7° (+5/+9°)	+5° (+3/+6°)	+4° (+2/+6°)	+3° (+1/+4°)	+9° (+6/+12°)	+6° (+4/+8°)	+4° (+3/+6°)	+3° (+1/+4°)
Average low in Dec-Jan-Feb	2°	8° (6–10°)	6° (5–8°)	6° (4–7°)	5° (3–6°)	10° (8–12°)	8° (6–10°)	7° (4–8°)	4° (4–6°)
Low temp of year's coldest night	-24°	-16° (-19/-13°)	-19° (-20/-15°)	-18° (-21/-16°)	-20° (-23/-19°)	-15° (-17/-9°)	-18° (-21/-10°)	-18° (-21/-14°)	-20° (-23/-17°)
Low temp of year's warmest night	45°	52° (50–54°)	50° (47–51°)	49° (48–51°)	48° (46–49°)	54° (52–57°)	51° (49–52°)	49° (48–51°)	48° (46–49°)
Nights per year with lows above 32°	83	141 (125–154)	124 (108–137)	119 (105–133)	107 (96–118)	160 (143–176)	135 (119–151)	123 (107–137)	108 (96–119)
Nights Nov 15–Apr 15 with lows above 32°	0.0	1 (0–2)	0 (0–1)	0 (0–1)	0 (0–0)	1 (1–3)	1 (0–1)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	47	21 (13–27)	26 (19–32)	27 (21–34)	33 (26–39)	15 (8–21)	22 (11–29)	27 (18–35)	35 (25–39)
May nights per year with lows above 32°	2	14 (10–18)	10 (7–13)	9 (6–13)	5 (4–7)	19 (15–23)	12 (9–19)	9 (6–14)	6 (4–8)
Days in frost-free growing season*	43	99 (75–113)	90 (63–100)	78 (61–97)	70 (51–82)	114 (92–135)	91 (71–110)	81 (68–97)	71 (51–83)
Extreme years									
Low temp of year's coldest night	-15°	-8° (-12/-5°)	-11° (-14/-6°)	-11° (-13/-9°)	-12° (-15/-7°)	-6° (-9/-1°)	-9° (-12/-3°)	-10° (-15/-6°)	-11° (-17/-8°)
Low temp of year's warmest night	49°	55° (53–57°)	52° (51–56°)	52° (50–55°)	51° (49–54°)	58° (55–61°)	54° (52–56°)	53° (50–56°)	51° (49–53°)
May nights per year with lows above 32°	6	24 (20–29)	19 (11–24)	18 (13–22)	12 (9–17)	28 (24–32)	22 (15–28)	19 (12–23)	12 (10–20)

Table 8. As Table 7 on the previous page, but with projections for the last two 20-year periods of the century.

With continued high emissions, late in the century there could be about 80 more nights a year above freezing in the Frisco/Dillon Reservoir area than in the baseline period.

Low temperatures in Breckenridge/Quandary grid, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	4°	+3° (+2/+4°)	+2° (+1/+3°)	+2° (+1/+3°)	+2° (+2/+4°)	+4° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+4°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	24°	+3° (+2/+4°)	+2° (+1/+3°)	+3° (+2/+3°)	+3° (+2/+4°)	+5° (+3/+6°)	+3° (+2/+4°)	+4° (+2/+5°)	+3° (+2/+4°)
Average low in Dec-Jan-Feb	0°	2° (1–3°)	1° (1–2°)	2° (1–3°)	2° (1–3°)	4° (2–5°)	3° (1–4°)	3° (2–4°)	2° (1–3°)
Low temp of year's coldest night	-24°	-22° (-23/-20°)	-23° (-26/-22°)	-23° (-24/-20°)	-23° (-24/-20°)	-20° (-22/–16°)	-22° (-24/-19°)	-21° (-23/-18°)	-21° (-24/-20°)
Low temp of year's warmest night	41°	45° (44–46°)	44° (43–44°)	44° (43–45°)	44° (44–45°)	47° (45–48°)	45° (44–46°)	46° (44–47°)	45° (43–46°)
Nights per year with lows above 32°	67	95 (85–101)	89 (83–97)	92 (84–98)	92 (85–101)	109 (100–120)	96 (87–105)	100 (87–112)	93 (85–104)
Nights Nov 15–Apr 15 with lows above 32°	0.0	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	61	46 (39–53)	51 (42–54)	46 (41–54)	47 (39–51)	38 (27–44)	41 (36–50)	40 (36–48)	45 (36–50)
May nights per year with lows above 32°	0.2	2 (1–3)	1 (1–2)	2 (1–3)	1 (1–2)	4 (2–7)	2 (1–3)	3 (1–5)	2 (1–3)
Days in frost-free growing season*	31	61 (47–72)	54 (42–64)	59 (43–68)	61 (49–69)	77 (60–89)	68 (50–74)	71 (50–80)	61 (46–72)
Extreme years									
Low temp of year's coldest night	-14°	-12° (-16/-8°)	-14° (-17/-10°)	-12° (-16/-10°)	-13° (-15/-9°)	-9° (-13/-6°)	-10° (-17/-8°)	-11° (-13/-9°)	-12° (-15/-9°)
Low temp of year's warmest night	45°	48° (47–50°)	47° (46–48°)	48° (46–48°)	47° (47–48°)	50° (49–52°)	49° (48–50°)	49° (47–51°)	48° (46–50°)
May nights per year with lows above 32°	3	9 (4–12)	7 (4–8)	8 (4–14)	6 (5–10)	14 (8–19)	10 (5–12)	9 (7–15)	9 (4–14)

Table 9. As Table 7 on page 27, but instead for the Breckenridge/Quandary grid.

Low temperatures in Breckenridge/Quandary grid, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels: 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	4°	+6° (+4/+8°)	+4° (+3/+6°)	+4° (+2/+6°)	+2° (+2/+4°)	+8° (+6/+10°)	+6° (+4/+8°)	+4° (+2/+6°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	24°	+8° (+5/+9°)	+5° (+3/+7°)	+4° (+3/+6°)	+3° (+2/+4°)	+10° (+7/+12°)	+6° (+4/+8°)	+5° (+3/+7°)	+3° (+2/+4°)
Average low in Dec-Jan-Feb	0°	6° (4–8°)	4° (2–6°)	4° (2–5°)	2° (1–4°)	8° (5–10°)	5° (3–7°)	4° (2–6°)	2° (1–4°)
Low temp of year's coldest night	-24°	-17° (-20/-13°)	-20° (-22/-16°)	-19° (-22/-17°)	-21° (-23/-19°)	-17° (-18/-10°)	-20° (-21/-16°)	-20° (-22/-15°)	-21° (-24/-18°)
Low temp of year's warmest night	41°	49° (48–51°)	47° (45–49°)	46° (45–48°)	44° (43–46°)	51° (49–54°)	48° (46–50°)	47° (45–48°)	44° (43–46°)
Nights per year with lows above 32°	67	127 (115–140)	110 (96–125)	105 (93–120)	92 (83–106)	143 (132–160)	120 (108–136)	109 (96–125)	92 (83–106)
Nights Nov 15–Apr 15 with lows above 32°	0.0	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–1)	0 (0–0)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	61	30 (19–37)	37 (26–42)	37 (30–45)	44 (35–52)	23 (14–30)	31 (19–39)	37 (27–48)	46 (33–52)
May nights per year with lows above 32°	0.2	9 (5–11)	5 (2–6)	3 (2–6)	2 (1–3)	13 (9–19)	7 (4–10)	4 (2–8)	2 (1–3)
Days in frost-free growing season*	31	92 (72–104)	79 (55–92)	74 (53–88)	60 (38–72)	106 (88–126)	86 (68–101)	75 (62–90)	61 (39–73)
Extreme years									
Low temp of year's coldest night	-14°	-6° (-11/-4°)	-12° (-15/-8°)	-11° (-12/-8°)	-12° (-14/-9°)	-5° (-9/-2°)	-8° (-12/-6°)	-9° (-11/-7°)	-11° (-16/-7°)
Low temp of year's warmest night	45°	53° (51–55°)	50° (49–52°)	49° (48–51°)	48° (47–51°)	55° (53–59°)	51° (50–53°)	50° (48–51°)	48° (46–50°)
May nights per year with lows above 32°	3	21 (14–24)	14 (6–17)	13 (8–18)	8 (3–10)	23 (19–30)	17 (11–23)	12 (8–20)	8 (6–13)

Table 10. As Table 9 on the previous page, but with projections for the last two 20-year periods of the century.

Low temperatures in Vail Pass/North Tenmile Creek grid, 2020–2059

	1970-99 Actual	Projections with Different Emission Levels: 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Typical years									
Cold months avg low (Nov thru Apr), change	3°	+3° (+2/+3°)	+2° (+1/+3°)	+2° (+1/+3°)	+2° (+2/+4°)	+4° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+4°)	+3° (+2/+4°)
Hot months avg low (May thru Oct), change	23°	+3° (+2/+3°)	+2° (+1/+3°)	+2° (+2/+3°)	+3° (+2/+3°)	+5° (+3/+6°)	+3° (+2/+4°)	+3° (+2/+5°)	+3° (+2/+4°)
Average low in Dec-Jan-Feb	-2°	1° (0/+2°)	0° (-1/+1°)	1° (-1/+2°)	1° (+0/+1°)	3° (+1/+4°)	1° (0/+3°)	2° (+1/+3°)	1° (0/+2°)
Low temp of year's coldest night	-26°	-23° (-25/-22°)	-25° (-27/-23°)	-25° (-26/-21°)	-24° (-26/-22°)	-21° (-24/-18°)	-23° (-25/-20°)	-22° (-25/-19°)	-23° (-26/-21°)
Low temp of year's warmest night	41°	44° (43–45°)	43° (42–44°)	43° (42–44°)	44° (43–44°)	45° (43–47°)	44° (43–45°)	45° (43–45°)	44° (42–45°)
Nights per year with lows above 32°	54	83 (74–89)	77 (68–81)	80 (71–85)	81 (71–88)	96 (88–109)	84 (76–94)	89 (75–101)	81 (71–94)
Nights Nov 15–Apr 15 with lows above 32°	0.0	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	66	51 (44–58)	56 (49–58)	51 (47–58)	51 (45–58)	41 (32–48)	46 (41–55)	46 (40–53)	51 (41–55)
May nights per year with lows above 32°	0.2	1 (1–2)	1 (0–1)	1 (0–2)	1 (1–1)	3 (2–5)	1 (1–2)	2 (1–3)	1 (1–2)
Days in frost-free growing season*	21	47 (33–57)	42 (29–46)	44 (34–52)	49 (34–54)	65 (48–80)	54 (40–61)	55 (37–66)	47 (34–59)
Extreme years									
Low temp of year's coldest night	-16°	-13° (-16/-8°)	-14° (-18/-10°)	-13° (-17/-11°)	-13° (-17/-10°)	-11° (-15/-6°)	-11° (-17/-9°)	-12° (-15/-10°)	-14° (-16/-11°)
Low temp of year's warmest night	44°	46° (44–48°)	46° (44–46°)	46° (44–47°)	46° (45–48°)	48° (47–49°)	47° (46–48°)	47° (46–49°)	46° (45–48°)
May nights per year with lows above 32°	2	6 (3–11)	5 (3–8)	6 (3–11)	5 (3–8)	10 (7–16)	5 (3–8)	7 (4–11)	5 (5–11)

Table 11. As Table 7 on page 27, but with respect to the Vail Pass/North Tenmile Creek grid.

Low temperatures in Vail Pass/North Tenmile Creek, 2060–2099

	1970-99 Actual	Projections with Different Emission Levels 2060–2079 High	Med. #1	Med. #2	Low	2080–2099 High	Med. #1	Med. #2	Low
Typical years									
Cold months avg low (Nov thru Apr): *change*	3°	+6° (+4/+8°)	+4° (+3/+6°)	+4° (+2/+5°)	+2° (+2/+4°)	+8° (+6/+10°)	+6° (+4/+8°)	+4° (+3/+6°)	+3° (+2/+4°)
Hot months avg low (May thru Oct): *change*	23°	+7° (+5/+9°)	+5° (+3/+6°)	+4° (+2/+6°)	+3° (+1/+4°)	+9° (+7/+12°)	+6° (+4/+8°)	+4° (+3/+6°)	+3° (+1/+4°)
Average low in Dec-Jan-Feb	-2°	4° (3–7°)	3° (1–4°)	2° (1–4°)	1° (0–2°)	6° (4–9°)	4° (2–6°)	3° (1–4°)	1° (0–3°)
Low temp of year's coldest night	-26°	-19° (-21/-15°)	-22° (-23/-18°)	-21° (-23/-19°)	-23° (-25/-21°)	-18° (-20/-11°)	-21° (-23/-13°)	-21° (-24/-17°)	-23° (-26/-20°)
Low temp of year's warmest night	41°	47° (46–49°)	46° (43–47°)	45° (44–46°)	44° (42–45°)	50° (48–53°)	47° (44–48°)	45° (44–47°)	44° (42–45°)
Nights per year with lows above 32°	54	117 (104–132)	98 (81–115)	95 (80–108)	80 (69–93)	136 (119–154)	109 (93–126)	95 (84–114)	81 (67–94)
Nights Nov 15–Apr 15 with lows above 32°	0.0	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Nights per year with lows below 0°	66	34 (22–42)	41 (31–48)	40 (35–49)	49 (40–56)	26 (16–35)	35 (23–44)	42 (32–52)	52 (40–56)
May nights per year with lows above 32°	0.2	6 (3–9)	3 (2–5)	2 (1–4)	1 (0–2)	10 (7–16)	4 (2–7)	2 (1–5)	1 (1–2)
Days in frost-free growing season*	21	83 (66–102)	65 (42–81)	61 (43–77)	46 (28–61)	100 (76–119)	74 (53–93)	63 (48–82)	44 (27–61)
Extreme years									
Low temp of year's coldest night	-16°	-8° (-12/-6°)	-13° (-15/-7°)	-11° (-13/-9°)	-14° (-15/-9°)	-6° (-10/-3°)	-9° (-13/-5°)	-11° (-14/-6°)	-12° (-17/-8°)
Low temp of year's warmest night	44°	51° (48–53°)	47° (46–51°)	47° (45–49°)	46° (45–49°)	53° (51–56°)	49° (47–52°)	48° (46–51°)	46° (45–48°)
May nights per year with lows above 32°	2	16 (12–21)	11 (5–14)	10 (5–14)	5 (2–7)	22 (17–30)	15 (8–21)	9 (5–15)	6 (3–8)

Table 12. As Table 11 on the previous page, but with projections for the last two 20-year periods of the century.

4. Future Precipitation

For this report, 60 different precipitation values were analyzed, with key results summarized in this section and full results available online at www.rockymountainclimate.org/extremes/summit. Again in this section, statements in text are based on the tables at the end of the section unless indicated otherwise.

Projecting future precipitation is complex and challenging.[16] The precipitation projections presented here should be considered more uncertain than the temperature projections in the preceding section, for the following reasons.

First, modeling precipitation is more uncertain for a region, such as Colorado, located between areas where increases are clearly projected (in our case, to the north) and those where decreases are clearly projected (to our south).[17]

Second, model results are more varied for small areas, like those analyzed here, than for larger ones.[18]

Third, climate models do a better job in projecting overall precipitation amounts than extreme precipitation events.[19]

Fourth, today's climate models do not do a good job of simulating the North American monsoon and thunderstorms that drive much of Colorado's summer precipitation, making summer projections here more uncertain.[20] As a result, those projections in particular may understate the amount of precipitation in that season. And the projections for summer precipitation in particular often show broad disagreement among the models, with projections ranging from significant decreases to significant increases, as the tables at the end of this section show.

Finally, as a careful examination of the projections presented here shows, for precipitation (unlike for temperature) there often is not a clear relationship between more heat-trapping emissions and larger climate changes.

Still, there are some important precipitation values for which the models are in general agreement and for which the extent of the projected changes appears linked to the amount of future emissions, and we focus on them in this section.

> "Due to the greater level of complexity associated with modeling precipitation, scientific uncertainty tends to dominate in precipitation projections throughout the entire century, affecting both the magnitude and sometimes (depending on location) the sign [direction] of the projected change in precipitation."
>
> *U.S. Global Change Research Program*[21]

Precipitation probably to increase, mostly in cold months

Total annual precipitation amounts are generally projected to increase somewhat. For all three Summit County grids, all four emission scenarios, and all four future time periods, the median projections are for increases in precipitation amounts over the baseline period. Of those 48 combinations of grids, scenarios, and time periods, two of the median projections are for increases of 10 percent, and the rest are for single-digit percentage increases.

Note, however, that even with such general agreement among the models, that some of the models do project decreases, as shown by the values for the 10th percentiles of the projections in the parentheses that are part of the results reported below.

The **Vail Pass/North Tenmile Creek** grid with **high emissions** is used for the following examples.

Total precipitation is projected:

- In mid-century, to increase by an average of four percent (-4 to +13 percent), compared to the baseline period.
- Late in the century, to increase by nine percent (-1 to +15 percent).

Precipitation in cold months, November through April, is projected:

- In typical years in mid-century, to increase by seven percent (3–17 percent).
- Late in the century, to increase by seventeen percent (3–26 percent).

Within the six cold months, **winter precipitation** (in December-January-February) is projected:

- In mid-century, to increase by an average of ten percent (2 to 18 percent).
- Late in the century, to increase by an average of twenty percent (4 to 31 percent).

Precipitation in hot months, May through October, is suggested by the median projections to have little or no change—but several individual models project sizeable increases and several others show sizeable decreases, as shown by the wide range from the 10th to the 90th percentiles of the projections:

- In mid-century, an average increase of two percent (-16 to +8 percent).
- Late in the century, an average decrease of three percent (-19 to +9 percent).

Within the six hot months, **summer precipitation** (in June-July-August) is projected:

- In mid-century, to increase by an average of two percent (-14 to +15 percent).
- Late in the century, to increase by an average of one percent (-22 to +15 percent).

It is worth re-emphasizing the caveats from the previous page: Since the models appear not to well represent summer monsoons or thunderstorms, the projections for the hot months could be low. And the projections for the hot months and for summer show a wide spread, spanning from double-digit percentage decreases to double-digit percentage increases, further suggesting that these projections are uncertain. Even with these uncertainties, it would be reassuring if the models clearly project enough of an increase in hot season precipitation, especially summer (June-July-August) precipitation, to offset the inherent drying effect of the significantly higher temperatures projected for then. But that is not the case.

The projections for precipitation in cold and hot months are illustrated in Figure 11 on the next page, using the Vail Pass/North Tenmile Creek grid was an example.

Precipitation amounts in Vail Pass/North Tenmile Creek grid, 2020–2099

Percentage change compared to 1970–1999

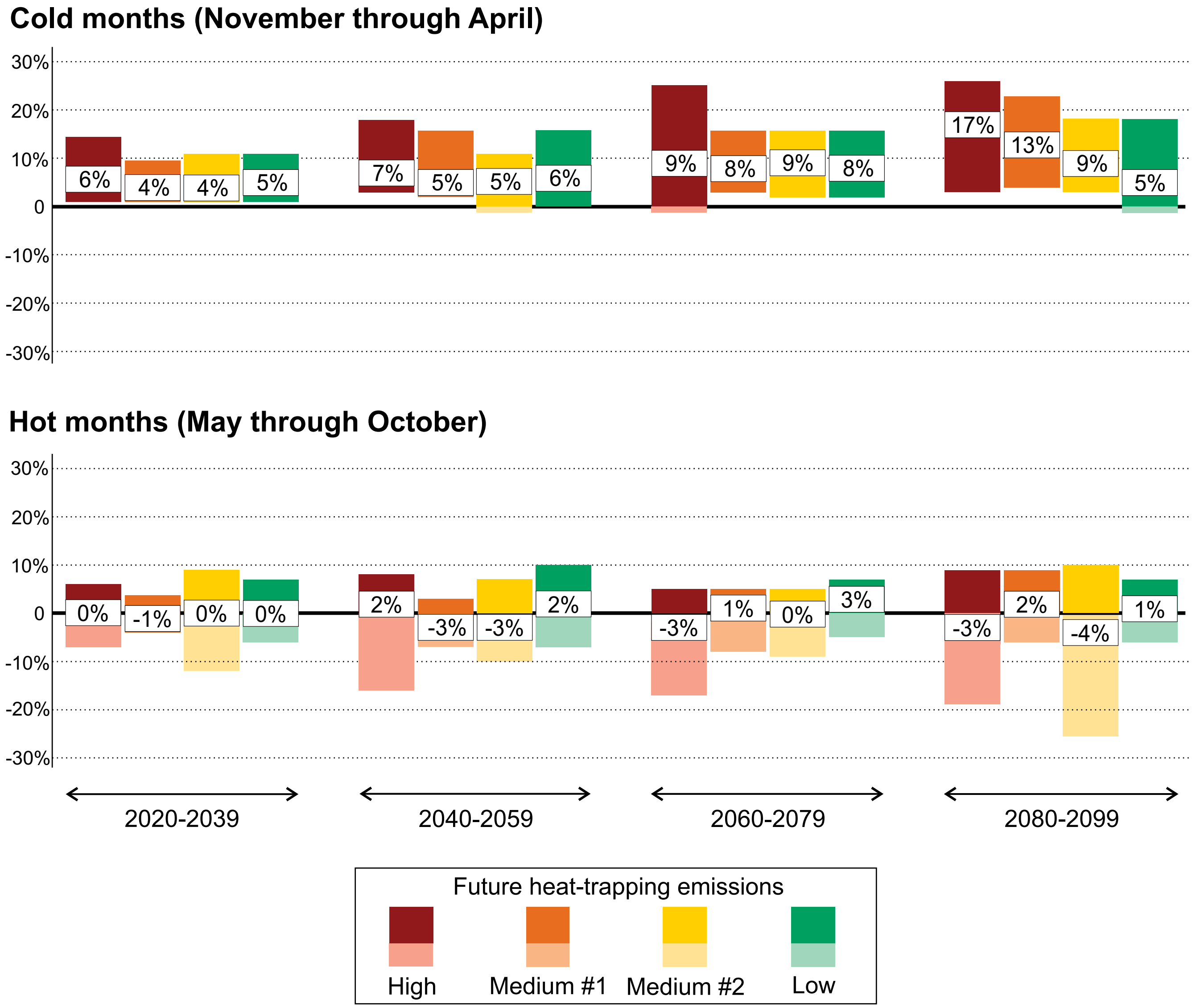


Figure 11. Projections for changes in the amounts of precipitation in the cold months of November–April and below that in the hot months of May–October, in percentage change compared to the gridded/observed amounts in the 1970–1999 baseline (see page 48). For each future period, the four columns represent separate projections based on the emission scenarios identified on page 7. The columns represent the range from the 10th percentile to the 90th percentile of the projections, and the numerals in the columns are the medians of all projections (see page 8), In a column, the darker color shows a projected increase and a lighter color a decrease. The gridded/observed 1970–1999 average precipitation amounts serving as baselines for the percentage changes illustrated here are 20 inches in the cold months and 11 inches in the hot months. For the data illustrated here, see tables 17 and 18 on pages 42 and 43.

Increases in winter precipitation are projected, especially with higher emissions. The models do not show an increase in summer precipitation.

Everyday precipitation events become less frequent, heavy storms more frequent

An even clearer, more consistent signal from the precipitation projections is that the frequency of storms of different intensity could change, with days of everyday, modest amounts of precipitation becoming less frequent and heavier storms becoming more frequent. The following examples, again, are from the **Vail Pass/North Tenmile Creek grid** with **high emissions**.

Routine wet days, those with less than a quarter-inch of precipitation in a day, are projected:

- In mid-century, to average 4 percent less frequent (-8 to 0%), compared to the baseline.
- Late in the century, to average 9 percent less frequent (-14 to -1 percent).

Storms of 1/4 inch to 1/2 inch of precipitation are projected:

- In mid-century, to average 15 percent more frequent (+4 to +29 percent).
- Late in the century, to average 23 percent more frequent (+9 to +41 percent).

Storms of 1/2 inch or more are projected:

- In mid-century to average 18 percent (+4 to +29) more frequent.
- Late in the century, to average 33 percent (+18 to +50 percent) more frequent.

The above projections are for the year-round frequency of these different wet days. The projections for increased frequency of heavy storms are even more pronounced in the cold months than in the hot months, especially with high emissions, as is shown by the tables on pages 38–43.

Figure 12 on the next page illustrates the changes in the projected annual frequency of different types of storms.

Frequency of storms by intensity, Vail Pass/North Tenmile Creek grid

Percentage change compared to 1970–1999

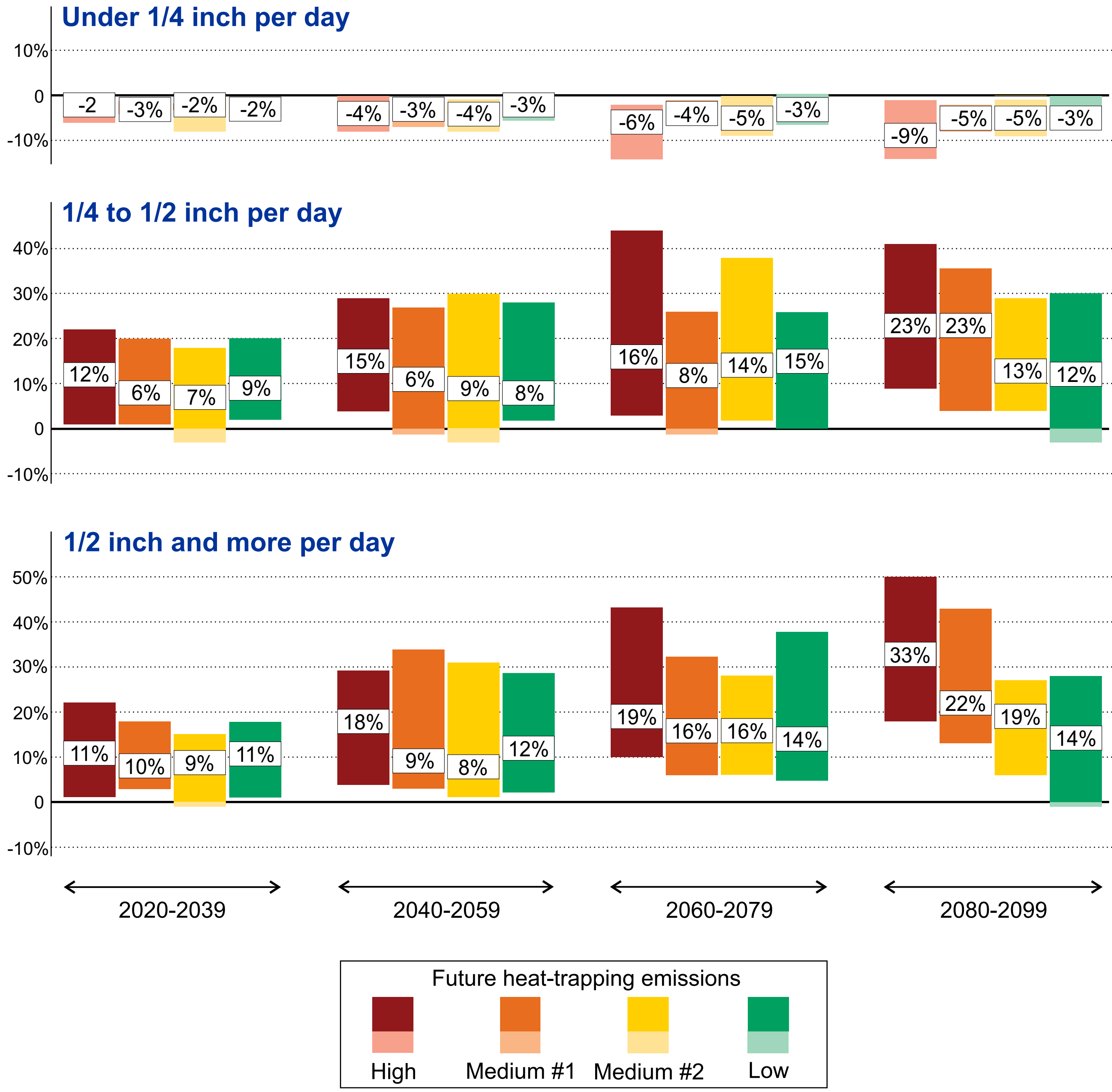


Figure 12. Projected percentage changes in the annual frequency of days of precipitation with the indicated precipitation amounts in the Vail Pass/North Tenmile Creek grid, otherwise as Figure 11 on page 35. The gridded/observed 1970–1999 average frequencies serving as baselines for the percentage changes illustrated here are averages of 180 days per year for storms of under 1/4 inch of precipitation per day, 28 days per year for 1/4 to 1/2 inch, and eight days per year for 1/2 inch and more. For the data illustrated here, see tables 17 and 18 on pages 42 and 43.

Heavy storms are projected to occur more often. The projected increases are larger with high emissions, and with high emissions the projections continue increasing through the century. This correlates with what would be increasing atmospheric levels of heat-trapping pollution.

Tables of Precipitation Projections

The table below and those on the next fives pages show key results of the analysis of projected precipitation for each of the three grids. As with the temperature tables, these are in pairs, with the first of each pair showing projections for 2020–2059 and the next for 2060–2099.

The results from the analysis of all 60 precipitation values done for this report are available online at www.rockymountainclimate.org/extremes/summit.

Precipitation in Frisco/Dillon Reservoir grid, 2020–2059

Percentage change compared to 1970–1999

		Projections with Different Emission Levels							
	1970-99	2020–2039				2040–2059			
	Actual	High	Med. #1	Med. #2	Low	High	Med. #1	Med. #2	Low
Precip amount in year	20 in.	+4% (-2/+9%)	+3% (0/+4%)	+2% (-4/+10%)	+4% (-1/+9%)	+4% (-6/+14%)	+2% (-1/+11%)	+2% (-7/+11%)	+3% (-2/+14%)
Cold months precip (Nov thru April)	11 in.	+7% (+1/+17%)	+4% (+2/+10%)	+4% (-4/+9%)	+6% (+1/+12%)	+8% (+2/+19%)	+5% (+2/+17%)	+6% (+1/+10%)	+6% (0/+18%)
Hot months precip (May thru October)	10 in.	0% (-8/+7%)	-2% (-3/+4%)	+1% (-12/+10%)	0% (-5/+8%)	+3% (-18/+9%)	-3% (-6/+4%)	-2% (-22/+12%)	+4% (-8/+12%)
Winter precip (Dec-Jan-Feb)	5.4 in.	+9% (-1/+17%)	+5% (-7/+12%)	+3% (-1/+9%)	+8% (0/+11%)	+11% (+2/+19%)	+3% (+2/+17%)	+6% (0/+9%)	+5% (0/+11%)
Spring precip (Mar-Apr-May)	6.0 in.	+3% (-5/+15%)	+2% (-4/+12%)	-2% (-11/+18%)	+5% (-5/+20%)	+3% (-3/+18%)	+4% (-4/+22%)	+5% (-5/+23%)	+4% (0/+23%)
Summer precip (Jun-Jul-Aug)	5.2 in	+1% (-9/+12%)	0% (-6/+6%)	-1% (-8/+12%)	+2% (-9/+9%)	+2% (-14/+16%)	-1% (-6/+2%)	+1% (-19/+15%)	+4% (-5/+12%)
Fall precip (Sep-Oct-Nov)	4.2 in.	+3% (-5/+9%)	+3% (-4/+9%)	+4% (-9/+11%)	+1% (-8/+7%)	-2% (-10/+10%)	+1% (-8/+8%)	+1% (-8/+9%)	0% (-11/+12%)
Days w/ less than 1/4 in. precip	178	0% (-5/+2%)	-2% (-3/-1%)	+1% (-5/+2%)	-2% (-5/+2%)	-2% (-7/+2%)	-2% (-6/+1%)	0% (-6/+3%)	0% (-6/+3%)
Days with 1/4 to 1/2 in. precip	16	+8% (+3/+17%)	+7% (+2/+13%)	+5% (-6/+21%)	+7% (+2/+18%)	+15% (+1/+24%)	+7% (0/+19%)	+7% (-6/+18%)	+10% (+3/+24%)
Days w/ 1/2 in. or more precip	2	+9% (-7/+23%)	+8% (+1/+14%)	+6% (-24/+60%)	+11% (-9/+22%)	+9% (-3/+23%)	+3% (-5/+18%)	+30% (-17/+64%)	+4% (-8/+24%)
Cold-month days w/ 1/2 in. or more	1.2	+9% (-9/+38%)	+13% (-3/+28%)	+10% (-23/+43%)	+13% (-12/+29%)	+14% (-5/+35%)	+8% (-4/+20%)	+31% (-7/+54%)	+9% (-18/+36%)
Hot-month days w/ 1/2 in. or more	0.9	+5% (-16/+20%)	-1% (-14/+19%)	+8% (-48/+102%)	-6% (-23/+29%)	+3% (-11/+15%)	+5% (-13/+19%)	+25% (-60/+90%)	+5% (-18/+20%)
Precip in wettest day in year	0.7 in.	+3% (-2/+11%)	+4% (0/+12%)	-4% (-15/+21%)	+3% (-5/+8%)	+4% (-1/+10%)	+3% (-1/+10%)	+4% (-14/+21%)	+3% (-5/+14%)

Table 13. Projections for percentage change in average amounts of precipitation in the Frisco/Dillon Reservoir grid, compared to the gridded/observed 1970–1990 values shown in the first column (see page 48), for the indicated time periods and the four emission scenarios identified on page 7. For the projections, the top row shows the median of the projections from all climate models for that emissions scenario, and the next row shows in parentheses the 10th percentile of the projections and the 90th percentile—in other words, the range of the middle 80 percent of those projections (see page 8).

Precipitation in Frisco/Dillon Reservoir grid, 2060–2099

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels: 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Precip amount in year	20 in.	+5% (-8/+17%)	+5% (-1/+12%)	+3% (-6/+15%)	6% (0/+12%)	+8% (-3/+15%)	+10% (-1/+16%)	+3% (-7/+13%)	+5% (-2/+12%
Cold months precip (Nov thru April)	11 in.	+10% (-1/+27%)	+8% (+5/+20%)	+9% (+1/+21%)	+8% (+2/+18%)	+18% (+3/+28%)	+14% (+3/+25%)	+14% (0/+17%)	+6% (0/+19%)
Hot months precip (May thru October)	10 in.	-2% (-17/+6%)	+2% (-9/+7%)	-5% (-21/+8%)	+3% (-6/+7%)	-1% (-18/+9%)	+3% (-6/+9%)	-5% (-32/+13%)	+2% (-6/+8%)
Winter precip (Dec-Jan-Feb)	5.4 in.	+9% (+3/+30%)	+9% (0/+16%)	+7% (+3/+12%)	+7% (-2/+13%)	+23% (+6/+33%)	+11% (0/+19%)	+10% (+3/+18%)	+5% (-4/+13%
Spring precip (Mar-Apr-May)	6.0 in.	+4% (-5/+27%)	+4% (-6/+25%)	+5% (-12/+27%)	+9% (0/+21%)	+7% (-7/+21%)	+12% (-3/+34%)	+4% (-8/+17%)	+9% (-2/+24%
Summer precip (Jun-Jul-Aug)	5.2 in	-3% (-21/+9%)	+3% (-4/+9%)	-7% (-25/+8%)	+3% (-10/+12%)	+1% (-23/+16%)	+6% (-7/+12%)	-8% (-30/+21%)	+3% (-7/+12%
Fall precip (Sep-Oct-Nov)	4.2 in.	-1% (-16/+9%)	-2% (-13/+7%)	+2% (-12/+8%)	+3% (-10/+13%)	-3% (-10/+13%)	+2% (-3/+13%)	+2% (-12/+12%)	+3% (-12/+8%
Days w/ less than 1/4 in. precip	178	-4% (-15/0%)	-2% (-6/+1%)	-2% (-9/+2%)	-1% (-5/+3%)	-7% (-12/+2%)	-3% (-8/+1%)	-4% (-10/+2%)	-2% (-6/+1%)
Days with 1/4 to 1/2 in. precip	16	+15% (+5/+41%)	+12% (+1/+22%)	+8% (-8/+29%)	+11% (+3/+23%)	+21% (+8/+39%)	+20% (+10/+32%)	+6% (-10/+30%)	+12% (-2/+23%
Days w/ 1/2 in. or more precip	2	+11% (+2/+39%)	+8% (-6/+24%)	+28% (-2/+84%)	+8% (-4/+21%)	+17% (+5/+42%)	+12% (-3/+22%)	+42% (-22/+90%)	+10% (-1/+21%
Cold-month days w/ 1/2 in. or more	1	+15% (-2/+51%)	+17% (-16/+38%)	+31% (-14/+91%)	+8% (-3/+33%)	+37% (+11/+71%)	+14% (0/+33%)	+60% (+8/+90%)	+14% (-4/+34%
Hot-month days w/ 1/2 in. or more	0.9	+5% (-15/+32%)	+7% (-9/+29%)	+21% (-36/+93%)	+4% (-13/+34%)	-4% (-22/+19%)	+3% (-15/+26%)	+27% (-85/+121%)	+6% (-4/+15%
Precip in wettest day in year	0.7 in.	+6% (+3/+12%)	+5% (0/+10%)	+8% (-6/+20%)	+5% (0/+10%)	+10% (+4/+17%)	+6% (0/+10%)	+2% (-12/+31%)	+4% (0/+8%)

Table 14. As Table 13 on the previous page, but for the last two 20-year periods of the century.

The median projections across all emission scenarios are for precipitation amounts in the six cold months of the year to increase, and days with a quarter-inch or more of precipitation to become more frequent.

Precipitation in Breckenridge/Quandary grid, 2020–2059

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels: 2020–2039 High	2020–2039 Med. #1	2020–2039 Med. #2	2020–2039 Low	2040–2059 High	2040–2059 Med. #1	2040–2059 Med. #2	2040–2059 Low
Precip amount in year	31 in.	+4% (-1/+9%)	+3% (0/+5%)	+1% (-3/+6%)	4% (-1+/8%)	+4% (-5/+13%)	+2% (-1/+11%)	+2% (-4/+7%)	+3% (-1/+13%)
Cold months precip (Nov thru April)	18 in.	+6% (+2/+17%)	+4% (+2/+9%)	+2% (-3/+5%)	+6% (+1/+12%)	+7% (+2/+18%)	+5% (+1/+17%)	+4% (+1/+6%)	+5% (0/+17%)
Hot months precip (May thru October)	13 in.	0% (-7/+6%)	-1% (-3/+5%)	+1% (-10/+8%)	0% (-4/+8%)	+2% (-16/+9%)	-2% (-7/+2%)	-1% (-17/+9%)	+2% (-7/+11%)
Winter precip (Dec-Jan-Feb)	9.0 in.	+7% (-1/+14%)	+4% (-7/+12%)	+2% (0/+5%)	+8% (0/+11%)	+10% (+2/+17%)	+3% (+2/+15%)	+3% (0/+5%)	+5% (+1/+10%)
Spring precip (Mar-Apr-May)	10.7 in.	+2% (-4/+12%)	+2% (-3/+12%)	-1% (-6/+10%)	+6% (-5/+17%)	+3% (-3/+16%)	+4% (-3/+22%)	+3% (-3/+13%)	+4% (0/+22%)
Summer precip (Jun-Jul-Aug)	5.9 in	+1% (-7/+13%)	-1% (-7/+6%)	-1% (-7/+11%)	+2% (-9/+9%)	+2% (-13/+15%)	0% (-6/+2%)	+1% (-17/+13%)	+5% (-9/+11%)
Fall precip (Sep-Oct-Nov)	6.1 in.	+2% (-5/+8%)	+3% (-3/+9%)	+3% (-6/+8%)	+1% (-7/+5%)	-2% (-10/+9%)	+1% (-7/+9%)	+1% (-5/+6%)	-1% (-11/+12%)
Days w/ less than 1/4 in. precip	159	-2% (-7/+1%)	-3% (-5/+2%)	+1% (-6/+3%)	-3% (-4/0%)	-3% (-8/+1%)	-4% (-7/-3%)	0% (-7/+3%)	-3% (-6/0%)
Days with 1/4 to 1/2 in. precip	29	+8% (-1/+19%)	+6% (+1/+8%)	+3% (-3/+11%)	+8% (0/+17%)	+11% (+3/+27%)	+6% (+1/+27%)	+4% (-3/+10%)	+9% (-3/+28%)
Days w/ 1/2 in. or more precip	10	+8% (+2/+13%)	+7% (-1/+12%)	+1% (-5/+13%)	+6% (0/+14%)	+12% (-1/+24%)	+3% (-1/+20%)	+6% (-4/+13%)	+8% (+1/+21%)
Cold-month days w/ 1/2 in. or more	7.3	+9% (+1/+21%)	+9% (-1/+17%)	+2% (-4/+7%)	+8% (-1/+14%)	+15% (+5/+27%)	+5% (-1/+22%)	+5% (-1/+9%)	+10% (0/+24%)
Hot-month days w/ 1/2 in. or more	2.5	0% (-12/+16%)	+3% (-14/+20%)	+3% (-17/+36%)	+7% (-15/+22%)	+11% (-22/+22%)	+5% (-20/+16%)	+9% (-21/+32%)	+5% (-4/+14%)
Precip in wettest day in year	1 in.	+5% (-2/+10%)	+5% (-3/+13%)	-2% (-9/+13%)	+3% (-4/+11%)	+5% (-2/+11%)	0% (-3/+9%)	+3% (-9/+13%)	+4% (-3/+11%)

Table 15. As Table 13 on page 38, but for the Breckenridge/Quandary grid.

Precipitation in Breckenridge/Quandary grid, 2060–2099

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels 2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Precip amount in year	31 in.	+5% (-6/+18%)	+4% (0/+13%)	+2% (-4/+10%)	+6% (0/+11%)	+8% (-1/+16%)	+10% (0/+16%)	+2% (-5/+9%)	+4% (-2/+12%)
Cold months precip (Nov thru April)	18 in.	+9% (0/+26%)	+8% (+4/+19%)	+5% (+1/+12%)	+8% (+2/+17%)	+17% (4/+26%)	+12% (+3/+23%)	+8% (0/+10%)	+5% (-1/+19%)
Hot months precip (May thru October)	13 in.	-3% (-17/+6%)	+1% (-9/+5%)	-4% (-16/+7%)	+3% (-5/+8%)	-3% (-18/+8%)	+3% (-7/+8%)	-4% (-25/+10%)	+2% (-6/+8%)
Winter precip (Dec-Jan-Feb)	9.0 in.	+8% (+3/+27%)	+9% (-1/+15%)	+4% (+2/+7%)	+7% (-2/+11%)	+21% (+4/+30%)	+10% (+1/+17%)	+6% (+2/+10%)	+5% (-4/+12%)
Spring precip (Mar-Apr-May)	10.7 in.	+4% (-3/+24%)	+4% (-6/+25%)	+3% (-6/+15%)	+8% (+1/+19%)	+7% (-5/+19%)	+11% (-2/+32%)	+3% (-4/+10%)	+8% (-2/+24%)
Summer precip (Jun-Jul-Aug)	5.9 in	-2% (-20/+8%)	+2% (-4/+10%)	-7% (-22/+7%)	+4% (-10/+13%)	+2% (-22/+14%)	+5% (-8/+13%)	-7% (-26/+18%)	+2% (-5/+11%)
Fall precip (Sep-Oct-Nov)	6.1 in.	0% (-15/+9%)	-3% (-10/+5%)	+1% (-7/+5%)	+3% (-9/+11%)	-3% (-10/+13%)	+4% (-4/+11%)	+1% (-8/+8%)	+3% (-11/+8%)
Days w/ less than 1/4 in. precip	159	-7% (-14/-2%)	-4% (-7/-1%)	-2% (-11/+2%)	-3% (-7/0%)	-9% (-14/-1%)	-6% (-10/-2%)	-4% (-11/+3%)	-4% (-7/+1%)
Days with 1/4 to 1/2 in. precip	29	+12% (-1/+42%)	+8% (-1/+24%)	+4% (-4/+16%)	+13% (-3/+22%)	+20% (+7/+40%)	+22% (-4/+35%)	+3% (-5/+16%)	+12% (0/+25%)
Days w/ 1/2 in. or more precip	10	+14% (+5/+33%)	+11% (+4/+25%)	+6% (0/+18%)	+10% (+4/+13%)	+22% (+10/+31%)	+18% (+6/+32%)	+9% (-5/+19%)	+6% (0/+24%)
Cold-month days w/ 1/2 in. or more	7.3	16% (+8/+38%)	+14% (+4/+28%)	+5% (-2/+15%)	+10% (+2/+19%)	+27% (+12/+39%)	+24% (+9/+39%)	+10% (+1/+15%)	+10% (+1/+25%)
Hot-month days w/ 1/2 in. or more	2.5	+6% (-26/+23%)	+3% (-11/+19%)	+7% (-12/+33%)	+10% (-13/+29%)	+2% (-13/+22%)	+8% (-5/+19%)	+10% (-30/+43%)	-7% (-7/+23%)
Precip in wettest day in year	1 in.	+6% (+2/+16%)	+2% (-2/+16%)	+5% (-4/+13%)	+4% (+1/+11%)	+9% (+6/+19%)	+7% (+1/+11%)	+1% (-8/+19%)	+5% (-4/+10%)

Table 16. As Table 15 on the previous page, but for the last two 20-year periods of the century.

By late in the century, the projected increases in precipitation with high emissions become larger.

Precipitation in Vail Pass/North Tenmile Creek grid, 2020–2059

Percentage change compared to 1970–1999

	1970-99 Actual	Projections with Different Emission Levels							
		2020–2039				2040–2059			
		High	Med. #1	Med. #2	Low	High	Med. #1	Med. #2	Low
Precip amount in year	31 in.	+4% (-1/+9%)	+2% (+1/+5%)	+1% (-2/+9%)	+4% (0+/9%)	+4% (-4/+13%)	+3% (-1/+11%)	+2% (-3/+9%)	+3% (-1/+13%)
Cold months precip (Nov thru April)	20 in.	+6% (+1/+15%)	+4% (+1/+9%)	+4% (+1/+11%)	+5% (+1/+11%)	+7% (+3/+17%)	+5% (+2/+16%)	+5% (-1/+11%)	+6% (0/+16%)
Hot months precip (May thru October)	11 in.	0% (-7/+5%)	-1% (-4/+4%)	0% (-12/+9%)	0% (-5/+7%)	+2% (-16/+8%)	-3% (-7/+3%)	-3% (-10/+7%)	+2% (-7/+10%)
Winter precip (Dec-Jan-Feb)	10 in.	+8% (0/+16%)	+5% (-7/+12%)	+4% (0/+10%)	+8% (-1/+11%)	+10% (+2/+18%)	+3% (+2/+16%)	+5% (-3/+10%)	+5% (+1/+11%)
Spring precip (Mar-Apr-May)	10 in.	+3% (-4/+12%)	+1% (-3/+11%)	0% (-3/+8%)	+5% (-4/+19%)	+3% (-3/+18%)	+5% (-4/+22%)	+1% (-3/+16%)	+4% (0/+21%)
Summer precip (Jun-Jul-Aug)	5 in	+2% (-8/+12%)	0% (-6/+6%)	+3% (-13/+14%)	+2% (-9/+9%)	+2% (-14/+15%)	0% (-6/+1%)	-5% (-10/+11%)	+4% (-5/+11%)
Fall precip (Sep-Oct-Nov)	6 in.	+1% (-6/+9%)	+2% (-3/+7%)	0% (-14/+13%)	0% (-7/+6%)	-2% (-10/+9%)	+2% (-6/+6%)	+1% (-7/+8%)	-1% (-10/+10%)
Days w/ less than 1/4 in. precip	180	-2% (-6/-1%)	-3% (-4/-2%)	-2% (-8/0%)	-2% (-5/-1%)	-4% (-8/0%)	-3% (-7/-2%)	-4% (-8/-1%)	-3% (-5/0%)
Days with 1/4 to 1/2 in. precip	28	+12% (+1/+22%)	+6% (1/+10%)	+7% (-3/+18%)	+9% (+2/+20%)	+15% (+4/+29%)	+6% (-1/+27%)	+9% (-4/+20%)	+8% (+2/+28%)
Days w/ 1/2 in. or more precip	8	+11% (+1/+22%)	+10% (+3/+18%)	+9% (-1/+15%)	+11% (+1/+18%)	+18% (+4/+29%)	+9% (+3/+34%)	+8% (+1/+31%)	+12% (+2/+29%)
Cold-month days w/ 1/2 in. or more	6.6	+11% (+1/+26%)	+15% (+5/+23%)	+10% (+2/+19%)	+13% (+3/+21%)	+21% (+3/+37%)	+13% (+3/+36%)	+10% (+2/+33%)	+13% (+3/+30%)
Hot-month days w/ 1/2 in. or more	1.4	-2% (-13%/+23%)	-1% (-21/+26%)	+2% (-13/+16%)	+8% (-13/+34%)	+15% (-26/+27%)	0% (-16/+33%)	+8% (-17/+24%)	+5% (-3/+24%)
Precip in wettest day in year	1.0 in.	+6% (-2/+12%)	+6% (-1/+10%)	+4% (-3/+9%)	+5% (-2/+10%)	+7% (0/+14%)	+4% (+1/+9%)	+5% (-2/+9%)	+6% (-4/+13%)

Table 17. As Table 13 on page 38, but for the Vail Pass/North Tenmile Creek grid.

Precipitation in Vail Pass/North Tenmile Creek grid, 2060–2099

Percentage change compared to 1970–1999

	1970-99 Actual	2060–2079 High	2060–2079 Med. #1	2060–2079 Med. #2	2060–2079 Low	2080–2099 High	2080–2099 Med. #1	2080–2099 Med. #2	2080–2099 Low
Precip amount in year	31 in.	+6% (-6/+18%)	+4% (0/+12%)	+5% (-2/+14%)	+6% (0+/11%)	+9% (-1/+15%)	+10% (+1/+16%)	+4% (0/+13%)	+5% (-2/+12%)
Cold months precip (Nov thru April)	20 in.	+9% (-1/+25%)	+8% (+3/+16%)	+9% (+2/+16%)	+8% (+2/+16%)	+17% (+3/+26%)	+13% (+4/+23%)	+9% (+3/+18%)	+5% (-1/+17%)
Hot months precip (May thru October)	11 in.	-3% (-17/+5%)	+1% (-8/+6%)	+2% (-11/+10%)	+3% (-5/+7%)	-3% (-19/+9%)	+2% (-6/+9%)	0% (-9/+5%)	+1% (-6/+7%)
Winter precip (Dec-Jan-Feb)	10 in.	+8% (+2/+26%)	+9% (0/+15%)	+8% (-3/+15%)	+7% (-1/+11%)	+20% (+4/+31%)	+9% (-1/+18%)	+10% (+3/+15%)	+4% (-4/+12%)
Spring precip (Mar-Apr-May)	10 in.	+4% (-4/+27%)	+4% (-6/+26%)	+6% (-2/+15%)	+9% (+1/+20%)	+7% (-5/+22%)	+12% (-2/+34%)	+6% (-3/+20%)	+8% (-2/+24%)
Summer precip (Jun-Jul-Aug)	5 in	-3% (-20/+8%)	+2% (-4/+9%)	+2% (-8/+13%)	+4% (-10/+13%)	+1% (-22/+15%)	+4% (-6/+12%)	+1% (-7/+11%)	+2% (-6/+11%)
Fall precip (Sep-Oct-Nov)	6 in.	0% (-16/+9%)	-4% (-11/+6%)	+3% (-10/+9%)	+3% (-9/+10%)	-4% (-11/+12%)	+3% (-6/+10%)	-1% (-8/+7%)	+3% (-11/+9%)
Days w/ less than 1/4 in. precip	180	-6% (-14/-2%)	-4% (-6/-1%)	-5% (-9/0%)	-3% (-7/0%)	-9% (-14/-1%)	-5% (-8/-2%)	-5% (-9/-1%)	-3% (-7/0%)
Days with 1/4 to 1/2 in. precip	28	+16% (+3/+44%)	+8% (-1/+26%)	+14% (+2/+28%)	+15% (0/+26%)	+23% (+9/+41%)	+23% (+4/+36%)	+13% (+2/+28%)	+12% (-3/+30%)
Days w/ 1/2 in. or more precip	8	+19% (+10/+43%)	+16% (+7/+32%)	+16% (+6/+28%)	+14% (+5/+28%)	+33% (+18/+50%)	+22% (+13/+43%)	+19% (+7/+27%)	+14% (-1/+28%)
Cold-month days w/ 1/2 in. or more	6.6	+23% (+11/48%)	+19% (+9/38%)	+18% (+6/34%)	+15% (+6/27%)	+39% (+19/56%)	+22% (+17/51%)	+23% (+3/38%)	+16% (+1/27%)
Hot-month days w/ 1/2 in. or more	1.4	+10% (-25/38%)	+1% (-14/13%)	+8% (-16/33%)	+9% (-9/32%)	+8% (-24/27%)	+14% (-5/37%)	+10% (-15/32%)	+8% (-6/27%)
Precip in wettest day in year	1.0 in.	+10% (+1/+14%)	+7% (0/+14%)	+6% (0/+12%)	+7% (+2/+9%)	+14% (+8/+19%)	+8% (+5/+13%)	+7% (+1/+12%)	+5% (0/+11%)

Projections with Different Emission Levels

Table 18. As Table 17 on the previous page, but for the last two 20-year periods of the century.

With high emissions, by late in the century storms of less than one-quarter inch of precipitation are projected to become nine percent less frequent.

But storms of one-quarter to one-half inch could become 23 percent more frequent. Even heavier storms, 33 percent more frequent.

5. Consequences

It is beyond the scope of this project to assess the impacts of the potential climate changes identified here, but there is an abundance of scientific information elsewhere that does that. The following summarizes a small sample of that information about just a few key impacts.

Increase in wildfires

- Higher temperatures increase the acreage burned in wildfires and the length of the wildfire season.[22] Climate change has been estimated to have doubled the area burned in the American West from 1984 through 2015.[23]
- Studies project major increases in wildfire in the Colorado mountains as climate change continues. Two examples: a report by the National Academy of Sciences projected a nearly seven-fold increase in this region in area burned with a modest 1.8° increase in global temperatures, and another study projected nearly a three-fold increase by mid-century with a medium level of future heat-trapping emissions.[24]

> "The duration of the season during which wildfires occur has increased throughout the western United States as a result of increased temperatures and earlier snowmelt. . . . By the middle of this century, the annual area burned in the western United States could increase 2–6 times from the present, depending on the geographic area, ecosystem, and local climate."
>
> *U.S. Global Change Research Program*[25]

Impacts of increased wildfires

- Increased wildfires obviously directly threaten people's safety and property, particularly as building expands in fire-prone areas.[26] More wildfire smoke also increases the risk of respiratory disease and mortality.[27]
- Heavy precipitation on burned areas leads to debris flows across the West, and those events are projected to increase with future increases in extreme storms and wildfires.[28] This summer in Colorado, mudslides from heavy storms over burned areas have repeatedly closed mountain highways.[29]
- Post-fire erosion from burned areas can adversely affect water quality and require expensive mitigation actions.[30] This summer, runoff from a storm over a burn scar has so polluted the Cache la Poudre River that treatment became impossible and Fort Collins had to stop using river water as a water supply.[31] After the 2002 Hayman fire, Denver Water had to spend $25 million in restoration costs to protect its water source in the area.[32]
- Wildfires and smoke can keep people from engaging in outdoor recreation activities.[33] More wildfires also can reduce summer tourism, even in areas not directly experiencing fires, and affect people's enjoyment of areas following fires.[34]

Skiing and other winter recreation and tourism

- The season for skiing, snowboarding, and other snow-dependent sports could be shorter and the snow slushier—reducing enjoyment for skiers, profits for skiing-dependent businesses, and tax revenues for state and local governments.[35]

- If ski areas do not experience long enough stretches of sub-freezing temperatures, it is conceivable they will not be able to maintain snowy slopes, regardless of whether they have snowmaking equipment or the water supply, shortening the length of the available ski season.[36]

"Resorts require a certain number of days just to break even; cutting the season short by even a few weeks, particularly if those occur during the lucrative holiday season, could easily render a resort unprofitable."

U.S. Global Change Research Program[37]

- Snowmobiling, cross-country skiing, and snowshoeing could experience the greatest declines in usage of all forms of outdoor recreation as the climate continues to change.[38]

Water availability and dryness

- Increased temperatures, especially the earlier occurrence of spring warmth, have already altered the water cycle across the West, with changes that include decreases in snowpack and its water content, earlier streamflows, and shifts in precipitation from snow to rain.[39] High temperatures due mainly to climate change have been estimated to account for 17%–50% of the record-setting reductions in the Colorado River between 2000 and 2014.[40]
- Higher temperatures inherently decrease water availability, by increasing evaporative losses from water bodies, soils, and plants, including crops.[41]
- Irrigation requirements are likely to increase for crops and other outdoor plants.[42]

Summer recreation and tourism

- Higher temperatures and reduced river flows clearly can reduce opportunities for fishing and rafting.[43]
- Other impacts to summertime recreation and tourism could include losses of visitation and visitor enjoyment, from causes ranging from temperatures too high for outdoor activities to disrupted transportation systems.[44]

Ecosystem effects

- Higher temperatures, especially if combined with drier summers, can increase tree mortality. Already, increases in background tree mortality (not including the effects of wildfires, insect infestations, or similar disruptions) have been detected in western forests, with particular increases in mortality of large trees, and changed climatic conditions have been determined to be largely responsible.[45] In Colorado, tree mortality in subalpine forests has increased in recent decades, with the greatest increases occurring during hot, dry periods.[46]
- Hotter and drier conditions can drive outbreaks of insects such as bark beetles as trees lose their resistance to infestations, allowing insect populations to grow to epidemic levels. A combination of warming temperatures in the winter allowing for greater number of mountain pine beetle larvae to overwinter and a longer growing season for the insects to produce have also contributed to the magnitude of recent West-wide bark beetle outbreaks, including in Colorado.[47] Winters with less intense cold and hotter summers have enabled bark beetles to reach outbreak levels at higher elevations than before.[48]

"Forest disturbance from epidemic bark beetle populations tracks closely with long-term precipitation levels and temperature patterns."

Colorado State Forest Service[49]

Especially when considered with additional scientific information on these and other possible impacts, the local climate projections analyzed in this report can help local governments, stakeholders, and the general public assess the possible future extent of these projected changes and their impacts in Summit County, and guide local public and private decisions about taking actions both for climate protection and for climate change preparedness.

6. Methodology

Climate projections

The climate projections used in this analysis were obtained from an online archive created by a consortium of partners: the U.S. Bureau of Reclamation, Climate Analytics Group, Climate Central, Lawrence Livermore National Laboratory, Santa Clara University, Scripps Institution of Oceanography, U.S. Army Corps of Engineers, U.S. Geological Survey, and National Center for Atmospheric Research and maintained on a website operated by Santa Clara University.[50] RMCO acknowledges and expresses appreciation to those collaborating organizations responsible for the online archive and also to the World Climate Research Program's Working Group on Coupled Modelling and the climate modeling groups for producing and making available their model output, and the U.S. Department of Energy's Program for Climate Model Diagnosis and Intercomparison and the Global Organization for Earth System Science Portals for their additional support with respect to the latest generation of models, which we used in this analysis.

The projections RMCO obtained are of daily climate values for maximum temperatures, minimum temperatures, and precipitation amounts from the latest generation of climate models, known as CMIP5 models, that have been downscaled by the consortium described above to produce results for grids 1/8 of a degree of longitude by 1/8 of a degree of latitude. The projections obtained are from the first listed ensemble from each available climate model for each emissions scenario—twenty models for the high emission scenario (officially known as Representative Concentration Pathway, or RCP, 8.5); twelve for the medium #1 scenario (RCP 6.0); nineteen for the medium #2 scenario (RCP 4.5), and sixteen for the low scenario (RCP 2.6).

The climate projections available on this archive have been widely used by many researchers with methodology like ours, including by Western Water Assessment for *Climate Change in Colorado*, its report to the Colorado Water Conservation Board (see page 4). An excellent general discussion of the climate models and their use is in that WWA report, from which the following points are taken.[51]

First, climate scientists have confidence that climate models can credibly project future climate conditions, for several reasons:

- The models are based on fundamental, well-understood scientific principles. (This is especially so for temperature, less so for precipitation.)
- The models are successful in replicating such climatic features as jet streams and ocean currents.
- Retrospective projections from the models successfully match historical climate conditions.

Second, projections from different models do differ, even with the same assumptions about future heat-trapping emissions. These differences reflect current scientific uncertainty on some key climate processes. When tested by how well the models retrospectively project the conditions of past years, combined results from all models are consistently more accurate than any single model is. But considering the range of results from the projections, not just an average value, captures the current uncertainties of the models. Accordingly, in this report, as WWA also did in *Climate Change in Colorado*, we present both the median (the mid-point) of all projections and also the 10th percentile and the 90th percentile of the projections—in other words, the range of the middle 80 percent of the projections (see page 8).

Third, despite recent improvements in climate models, they still have tendencies to over- or under-project certain climate aspects. A simple "delta method" approach, as used by WWA for *Climate Change in Colorado* and by RMCO for this report, effectively cancels out much of this bias.[52] In the case of this report, the downscaled projections from each model for a particular grid are compared to its retroactive projections for the baseline period of 1970–1999, and it is the difference that was analyzed for this report. Since a model that consistently overestimates temperatures, for example, would do so for the baseline period as well as for the future, by considering only how much the model's future projections differs from its retroactive projections compensates for any such bias. The model's projected differences from the baseline were then added to the gridded/observed values for the baseline period, described next, to produce the future values that were analyzed here..

Baseline observational data

The baseline data for 1970–1999 are observational data that have gridded to produce average values for each grid, and are available from the same online archive identified on the previous page. This baseline data is derived from weather station records, not from the models from which the projections are produced.

Newer models and scenarios

A newer generation of global climate models ("CMIP6") and a newer generation of emission scenarios was developed for and used in the United Nations's Intergovernmental Panel on Climate Change Sixth Assessment Report, of which the first part was released this month (August 2021).[53] Downscaled local results from these models are not yet available, and so the projections presented here remain the latest such projections that are available.

The new generation of emission scenarios now includes five—four that roughly correspond to the four scenarios used in the models analyzed here, and a new one with very low future emissions, reflecting an understanding in the scientific community of the need for even sharper emission reductions than those assumed in the low scenario considered here.

Notes

1. S. Saunders, T. Easley, and M. Mezger, *Climate Projections for Eagle County, Colorado*, report of the Rocky Mountain Climate Organization (RMCO) (Almont, CO: RMCO, 2021), http//www.rockymountainclimate.org/extremes/eagle.

2. S. Saunders, T. Easley, and M. Mezger, *Future Climate Extremes in Boulder County* and *Future Climate Extremes in Larimer County*, reports of RMCO (Louisville, CO: RMCO, 2016), http//www.rockymountainclimate.org/extremes/boulder and www.rockymountainclimate.org/extremes/larimer, respectively; S. Saunders, T. Easley, and M. Mezger, "Future extreme heat in the Denver metro area," report of RMCO (Louisville, CO: RMCO, 2017), http://rockymountainclimate.org/images/DenverHeatExtremes.pdf; and S. Saunders, T. Easley, and M. Mezger, "Future precipitation in the Denver metro area," report of RMCO (Louisville, CO: RMCO, 2017), http://rockymountainclimate.org/images/DenverPrecip.pdf.

3. U.S. Bureau of Reclamation and others, "Downscaled CMIP3 and CMIP5 climate and hydrology projections," http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/#Welcome. See also L. Brekke and others, 2013, "Downscaled CMIP3 and CMIP5 climate projections: Release of downscaled CMIP5 climate projections, comparison with preceding Information, and summary of user needs," http://gdodcp.ucllnl.org/downscaled_cmip_projections/techmemo/downscaled_climate.pdf.

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